The MagPi

TROUBLESHOOTING GUIDE

Fix your Raspberry Pi today!

Featuring **Raspberry Pi** 5

Machine Learning

Huge update to TinyML

#MonthOfMaking

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SSD add-on

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UL LISTED

Industrial Raspberry Pi

ComfilePi

The ComfilePi is a touch panel PC designed with high-tolerant components and no moving parts for industrial applications. It features a water-resistant front panel, touchscreen, color LCD (available in various sizes), RS-232, RS-485, Ethernet, USB, I2C, SPI, digital IO, battery-backed RTC (real-time clock), and piezo buzzer.

Use the rear-panel 40-pin GPIO header to expand its features and capabilities with additional I/O boards. The ComfilePi is UL Listed and employs Raspberry Pi Compute Module.

POWERED BY Raspberry Pi

CP-IO22-A4-2

COMFILE TECHNOLOGY

WELCOME
to The MagPi 139

Raspberry Pi puts you at the forefront of computer experimentation. It's an exciting place to be, albeit a tad precocious. That's why our Troubleshooting feature (**page 42**) is such a vital read. It's packed with information on how to overcome any snags you might encounter. Not only will this make your Raspberry Pi experience more enjoyable, but you'll also become a better computer expert.

This month sees the welcome return of #MonthOfMaking (**page 68**), where we all get together to show off the big builds we've been working on.

We've also got two cases that support the new PCIe drives: NVME Base (**page 76**) and Argon ONE V3 M.2 (**page 78**). Both will vastly speed up your Raspberry Pi 5.

Whatever you make with Raspberry Pi, be sure to share it with the community. We learn from each other and love seeing what everyone creates.

Lucy Hattersley-Haworth

Editor

EDITOR

Lucy Hattersley-Haworth

Lucy is editor of *The MagPi* and has spent a lot of time extolling the virtues of the Sega Dreamcast this month.
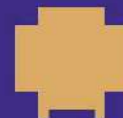
magpi.cc

GET A
RASPBERRY PI PICO W
WITH A SUBSCRIPTION!
PAGE **36**

Sometimes it's not about millions of parts. Sometimes it comes down to just one very specific part to keep your design moving forward. Chances are we have that part, and quite a few more when you need them.

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Contents

> Issue 139 > March 2024

42

32
SNES XL

20
PeggyBoard

Tutorials

Get to know your Raspberry Pi

Upcycle Sonos speakers - part 1

The Big Feature
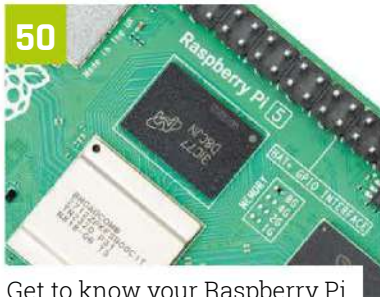

#MonthOf Making 2024

GENIUS CONTRAPTIONS

Get making in March and share your progress with the community!

#MonthOfMaking 2024

NVME Base

Reviews

Learn AI

Community

WIN 1 OF 5 ARGON ONE V3 CASES 96

TensorFlow Lite
speed bost

A big bang update for TensorFlow Lite
for Microcontrollers. By **Alasdair Allan**

The excitement around machine learning right now is all about generative AI, and the new generation of large language models (LLMs). But sometimes you should take a step back, and remember what we were all excited about last time. Because it could be time to get excited about it again.

Before LLMs made it big, we were all excited by embedded machine learning – what's called TinyML – and Raspberry Pi is probably the most affordable way to get started. The inferencing performance (**magpi.cc/bigbenchmarking**) we see with Raspberry Pi 4 was comparable to or better than some of the new accelerator

hardware, but your overall hardware cost is that much lower.

But what if you want to go really tiny – microcontroller tiny? We have actually seen some really crazy projects (**magpi.cc/picomonocam**) making use of our RP2040 chip, Raspberry Pi Pico, and the RP2040 port of TensorFlow Lite for Microcontrollers (**magpi.cc/tflmicro**). Unfortunately, since that port was done by Pete Warden, who at that point headed up the TensorFlow mobile team at Google, the RP2040 port has been languishing. But a couple of weeks ago, that all changed (**magpi.cc/tflmicropull12**).

> ❝ If you're thinking about doing some tiny machine learning, RP2040 just became your go-to platform ❞
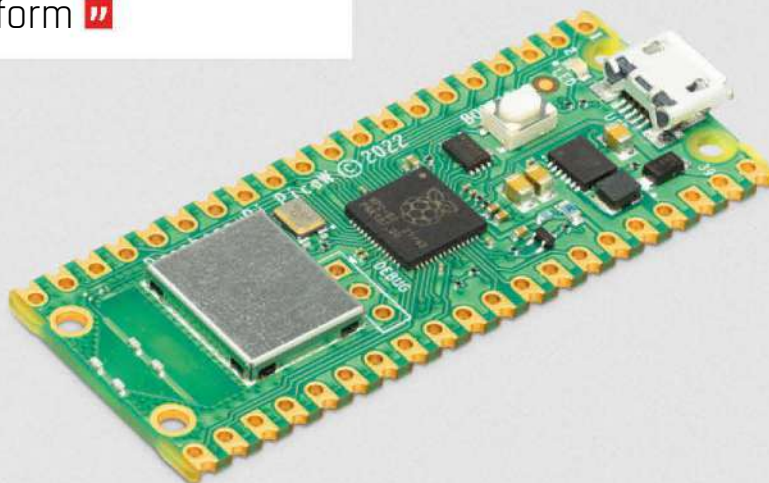
▶ A Raspberry Pi Pico W
board ready for
machine learning
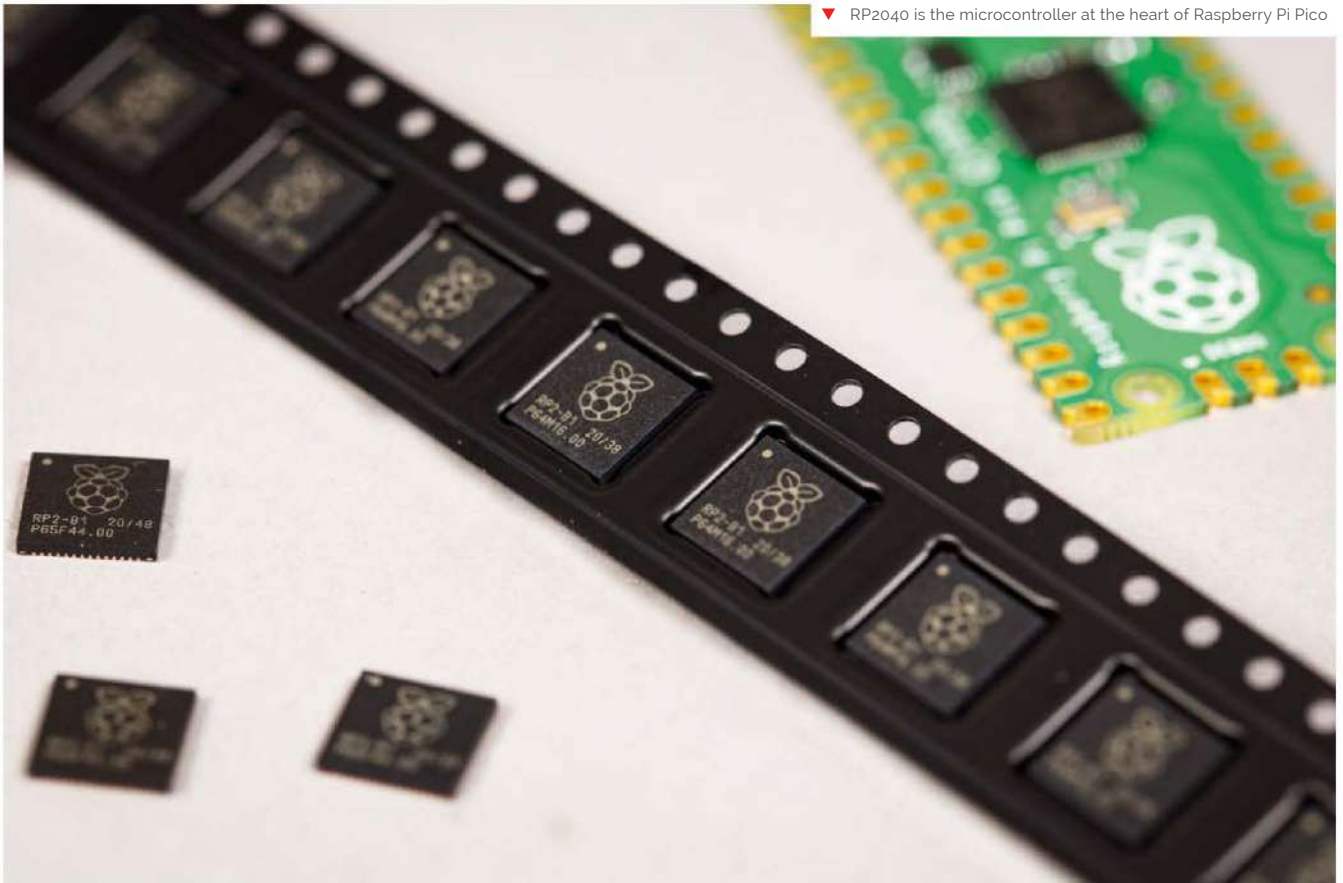
▼ RP2040 is the microcontroller at the heart of Raspberry Pi Pico

A pull request the size of Wales

Now at Useful Sensors (**usefulsensors.com**), Pete has been doing some interesting things (**magpi.cc/tinycodereader**) with RP2040. He has just upstreamed the last three years of changes – after all, as he puts it, "We all love pull requests with 1,129 changed files, right?" – and he's taking on maintenance of the port on a best-effort basis.

Dual-core support on RP2040

But there's more: beyond that, Pete has updated the port, speeding up the default CMSIS-NN implementation for Conv2D by splitting it across both cores on the RP2040, and adding dual-core optimisations to depthwise convolutions. For the first time, we have dual-core support for TensorFlow on RP2040! If you're interested in some of the detail behind the updates, Pete has put together a fascinating write-up (**magpi.cc/picomemorylayout**) of the memory layout issues he ran into while debugging the optimisations.

The upshot? These updates and changes reduce the time for the person detection benchmark (**magpi.cc/persondetection**) code from 824ms to 588ms. That's a ×1.4 speed increase!

If you're thinking about doing some tiny machine learning, RP2040 just became your go-to platform (**magpi.cc/tflmicro**).

GitHub Universe attendees treated to custom RP2040 Badgers

Raspberry Pi RP2040 was used to create custom badges for GitHub Universe attendees. By **Ashley Whittaker**

▼ The custom Badger2040 kit handed out to GitHub Universe attendees

We move in the kind of circles where news of the GitHub Universe (githubuniverse.com) conference lights up our social feeds each year. This time (well, now it's last time) we were super excited to see photos of the official conference badges. We noticed they look a lot like a Pimoroni Badger, which is powered by our RP2040 chip (**magpi.cc/rp2040**), so we took a closer look to see if we were right.

Special custom gift

GitHub's Martin Woodward made a dedicated repo (**magpi.cc/badger2040git**) to help conference attendees learn how to hack their badges. Lo and behold, in it he confirms that the hackable conference badges are indeed a custom version of the Badger 2040 (**magpi.cc/badgerguide**) that Pimoroni made especially for GitHub.

> " GitHub Universe Badger is electronically identical to the original Badger 2040 "

An RP2040 is running MicroPython which throws text up on a built-in 2.9-inch E Ink display. All five buttons dotted around the edge of the screen are user-configurable, and there's also a Stemma QT expansion port so you can connect your own accessories, such as sensors. You can power the badge via its USB-C port, or use either a 2 × AAA battery pack or a standard 3.7V LiPo cell. It's "extremely low power", according to Martin, which is what you need when you're wandering around a conference all day and don't want to be tied to a power outlet.

Open source ideas

Custom PCB aside, the GitHub Universe Badger is electronically identical to the original Badger 2040. This means conference attendees can make use of all the open-source examples already out there, as people have shared cool things they've done with their Badger – the devices aren't tied to a one-time use as a conference badge. Pre-loaded goodies on the GitHub Universe Badger include an eBook reader, to-do list, and image viewer.

Want cool badges for your event?

Martin's GitHub repo pointed us towards Badge. team (**badge.team**), an open-source community for people who want to create excellent badges for events. There are some magical designs on display in the gallery already. They're also looking for volunteers to support the project, so join their Telegram group (**magpi.cc/badgetele**) or Discord channel (**magpi.cc/badgedisc**) if you think you can help people make next-level event badges.

▲ A custom Badger 2040 badge handed out at GitHub Universe

◀ The PCB is a custom-built conference badge running Micropython on the RP2040 microcontroller

FREISA

Every dog has its day and this is FREISA's time to shine.
David Crookes takes a look at an innovative plant-watering system

MAKER

B-AROL-O Team

The talented international team consists of Gianluca Tetri, Gianpaolo Macario, Pietro d'Agostino, Davide Macario, Andrea Podo and Orso Eric

magpi.cc/freisa

Real dogs tend to be fluffy and cute. Robodogs rather less so. But when you meet FREISA, a robotic dog created for a recent competition, you'll still want to give it a pat on the back and heap it with praise. For, just like its living, breathing canine counterparts, this impressive little thing is intelligent and skilled. It's capable of spotting a thirsty plant and making sure it gets enough water.

FREISA – an acronym for Four-legged Robot Ensuring Intelligent Sprinkler Automation – is the brainchild of the B-AROL-O Team. This group won the popular vote of the OpenCV Spatial AI Contest in 2022 by creating a packaging machine called ARNEIS using Raspberry Pi 4B, a Spatial AI camera and an assortment of LEGO Technic parts.

Seeking to make a similar impact in last year's competition, they got their heads together once again. "As implied by our team name, our familiarity with vineyards inspired us to develop an automated watering system aimed at assisting on a farm," says one of the group, Gianluca Teti. The idea was to use computer vision to water plants and come up with a device capable of carrying out the work.

They ruled out creating a robot running on wheels and tracks, noting that it would be poor at clearing obstacles over rough ground. The group also briefly considered a quadcopter but felt its battery and payload would be poor. A quadruped legged platform was chosen because of its ability to navigate complex terrain.

"We initiated a brainstorming session with the team to assess our available hardware options for the project," Gianluca adds. "Orso Eric, one of our team members, owned a Mini Pupper 2. Consequently, we collectively agreed to utilise that specific model for our project."

Re-tail therapy

The Mini Pupper 2 is an open source robot kit that sprang into life off the back of a crowdfunding campaign. The quadrupedal robot supports Raspberry Pi, which the team planned to use to handle FREISA's navigation. To ensure it would be suitable as a robot plant waterer, an OAK-D Lite camera boasting SpatialAI functionality was connected. This camera can run computer vision pipelines on dedicated hardware which, the team surmised, would reduce the burden on Raspberry Pi's resources.

To ensure the project would actually be suitable for its intended purpose, the team carried out some research. "We conducted interviews with several experienced farmers and gardeners," says Gianluca. "Their insights suggested that visually inspecting plants can offer a reliable assessment of their condition."

> **The team got to work, training two neural networks**

With this in mind, the team got to work, training two neural networks to work out which plants would need watering and which ones would not. By this point, they had ditched the idea of analysing vines because they noted the leaves would grow too high for the robot to see them, and the vineyard terrain would be too uneven. Instead, they decided to concentrate their efforts on a household garden populated with tomato plants.

"The objective was to assess a plant's condition by analysing the state of its leaves and stems," Gianluca

The OAK-D Lite 12.3 MP camera contains an AI processing chip and features 300,000-point stereo depth

The project's Raspberry Pi 4 Model B controls the motion of the robot and the mechanical sprinkler so that the targets can be watered

Rather than create a robot dog from scratch, the project has been based on the open-source Mini Pupper 2 which supports the Robot Operating System and Raspberry Pi

Quick **FACTS**

> It's built around a Mini Pupper 2 robot frame

> It runs Ubuntu, Docker and OpenCV

> An OAK-D Lite camera captures and processes the images

> It can detect unhealthy leaves on tomato plants

> There's a water sprinkler system on board

▲ The Mini Pupper 2 comes in kit form, so one of the first tasks was to assemble all of the parts.

▲ The Mini Pupper 2 starts to take shape, allowing the team to begin work on their watering project

explains. "Our approach began with collecting a vast array of images and then training various networks and models. Our infrastructure consisted of one desktop computer – featuring an AMD Ryzen 2600X CPU, 48 GB of RAM, and an NVidia GTX 1660 Super GPU – running Ubuntu 23.04 and accessible remotely via a JupyterLab container."

Petting on success

For the time being, the team decided that using visuals would be sufficient, although there is scope to further improve accuracy. "Integrating additional sensors – such as those measuring humidity, temperature and so on – into the FREISA project's framework could be beneficial," Gianluca says. "The architecture of the FREISA project appears adaptable enough to readily accommodate these supplementary sensors."

By using Ubuntu rather than Raspberry Pi OS, the team says their work was made a little easier. "Our decision leaned towards an Ubuntu server over Raspberry Pi OS, despite their potential equivalence for our current application, because Ubuntu stands as the primary supported platform for ROS (Robot Operating System), a framework we intend to implement soon to expand the capabilities of our platform for additional use cases," Gianluca explains.

Having Raspberry Pi on board, however, has worked extremely well. "Raspberry Pi serves as an exceptional hardware foundation, notably due to its extensive array of open-source software and programming tools," Gianluca continues. "Furthermore, the Mini Pupper 2 is constructed using the Raspberry Pi Compute Module 4, aiding in space and weight reduction, consequently enhancing the available payload on the robot dog."

Round of a-paws

The great news is that the project – which makes use of Docker (a software platform that lets developers quickly build, test and deploy applications) and OpenCV – has been effective. The robot has a sprinkler in a pelvic position with the water reservoir above it, and it's able to move freely to quench a plant's thirst.

"Our robot demonstrates good abilities in identifying a target plant, navigating towards it, and examining its leaves before precisely adjusting its position to efficiently water the plant," Gianluca

▶ The Mini Pupper 2 also has support for Raspberry Pi Compute Module 4

explains. Even so, there have been challenges; some practical and some logistical. "The primary hurdle we encountered was identifying the most suitable terrain for deploying the watering system," he continues.

"A secondary challenge involved effectively coordinating tasks among a team comprising

> ❝ FREISA won the Grand Prize in 2023's OpenCV AI Competition ❞

four active members and two advisors situated across various locations worldwide: the US, France and Italy.

"To overcome these challenges, we implemented an agile development workflow based on weekly sprints. With the help of a CI/CD pipeline built with GitHub and other online resources, team members collaborated effectively, enabling successful project management and task allocation despite geographical distances."

FREISA won the Grand Prize in 2023's OpenCV AI Competition. Still, the team isn't going to rest on its laurels. It's already identified potential improvements such as using the OAK–D Lite's stereo camera to estimate a target's distance. Just goes to show, you can't keep a good dog down.

▼ When creating the water and targeting systems, the team needed to consider weight distribution

Watering the plants

01 FREISA utilises its camera and a machine learning algorithm trained using Roboflow (**roboflow.com**) to tell the robot's navigation system where the plants are located. It will analyse the state of the leaves and work out which plants require watering.

02 If it identifies dried-up plants, the robot will then ready itself. It will use its legs to get into position so that the robot's pelvic-located 3D-printed water sprinkling system (which includes a reservoir) is able to best target the thirsty plant.

03 At this stage, the sprinkling system bursts into action thanks to servomotors and a syringe that is able to draw up 10ml of water. The water is then dispensed on to the plant, and this is confirmed to the plant's owner, keeping a log of the event.

Mac Mini
KVMac16

Fixing Macs remotely with Raspberry Pi. By **Rosie Hattersley**

MAKER

Ivan Kuleshov

Ivan loves taking apart different devices to improve them, or learn how they work, and can't resist a hardware challenge.

magpi.cc/ uptimelab

Self-confessed "hardware hacker" Ivan Kuleshov really likes making things. He's adept at using tools covering everything from microscopes to lathes, builds and flies drones and has won three separate hackathons. As long as he can remember, he's been beavering away on various projects related to hardware, from PC modding to the creation of homemade devices, racking up more than nine years on 3D printing and modelling. This aspect briefly became a business venture, but his day job is as a systems engineer in Munich with a string of certifications. His computing, coding and design skills also came in handy for his Mac Mini KVMac16 project, for which the goal was simple: to provide full access to a Mac mini in a remote data centre, with a bit of help from Raspberry Pi 4.

The right tools

Ivan values Raspberry P's modularity which allows him to create unique devices and has previously used various models including Compute Module 4 in his Compute Blade (**magpi.cc/computeblade**), an energy-efficient alternative to a rack-mounted server. He praises the "relatively cheap minicomputer with a huge community, which greatly lowers the threshold of entry and increases trust".

For the Mac Mini KVMac16 project – Ivan describes it as "a console for 16 Mac minis on a shelf that occupies a 6U space in a server rack" – Raspberry Pi is used as a KVM (kernel-based virtual machine) while "the PiKVM HAT is used for video capture and keyboard/mouse command transfer". Ivan chose Raspberry Pi because it both supports the components and offers long-term software support. He says: "Raspberry Pi 4 with 4GB is easily sufficient for the task".

> ❝ Ivan chose Raspberry Pi because it both supports the components and offers long-term software support ❞

As Ivan's blog explains, should a Mac go down due to a failed update or any another reason, the only way to reboot it is to physically press its power button. This is not something that can be done remotely, and is the issue his KVMac device

KVMac16 helps get an offline Mac mini back up and running should an update or other issue cause it to be out of action

Ivan designed and 3D printed the Mac mini server rack too!

A Servo HAT administered through PiKVM's user interface, and managed by Raspberry Pi 4, physically pushes the power button to restart Mac mini and bring it back online

▶ Ivan's 'perfect shelf' for his Mac mini project allows air to circulate while being very robust

Quick **FACTS**

> The Mac Mini KVMac16 project cost just under €2,000

> It involved two weeks of 3D printing

> And around a year of development

> Alongside Ivan's many other hardware projects

> He's thinking of a potential desktop version in future

▼ Ivan designed his own stand for the 16-strong Mac mini server setup

addresses. "To provide full control, with the ability to completely reinstall the OS, you need to press the power button and there are no other options." Ivan has created the optimal workaround: a Servo HAT and self-written Python scripts control the servos used to physically push buttons on the Mac mini. He also uses RS232 to control a regular KVM switch from the user interface between a Raspberry Pi PiKVM HAT and 16 Mac minis, through which he can connect to any of them.

Third time's a dream

As Ivan details on his Uplab blog (**magpi.cc/ kvmrackstand**), creating the KVM Mac Mini project involved three different versions, with improvements each time focusing on ease of installation and overall reliability. PiKVM is at the heart of the project, and provides a basic user interface, "but the ability to physically push buttons, and the 16 Mac mini install stand itself, are designed by me from scratch [as were the] custom scripts and UI modifications to give the user full control".

Many of the challenges were because the project uses servos and levers to push buttons on the Mac minis, which need to work with maximum reliability. He started the project from scratch three times and counsels other would-be makers that if you find your project moving in the wrong direction, stop, reappraise and "have the strength to start over from scratch". Ivan did this twice here, and says it strengthened his project as well as validating the potential for both a four-Mac mini model and a potential CI/CD one (Continuous Integration Continuous Deployment).

It is just as well that Raspberry Pi proved a good option. Ivan says there are "simply no alternatives. This project was only possible thanks to Raspberry Pi and PiKVM. M

▼ The PiKVM 3 virtual machine provides a custom interface through which Ivan controls his Mac minis
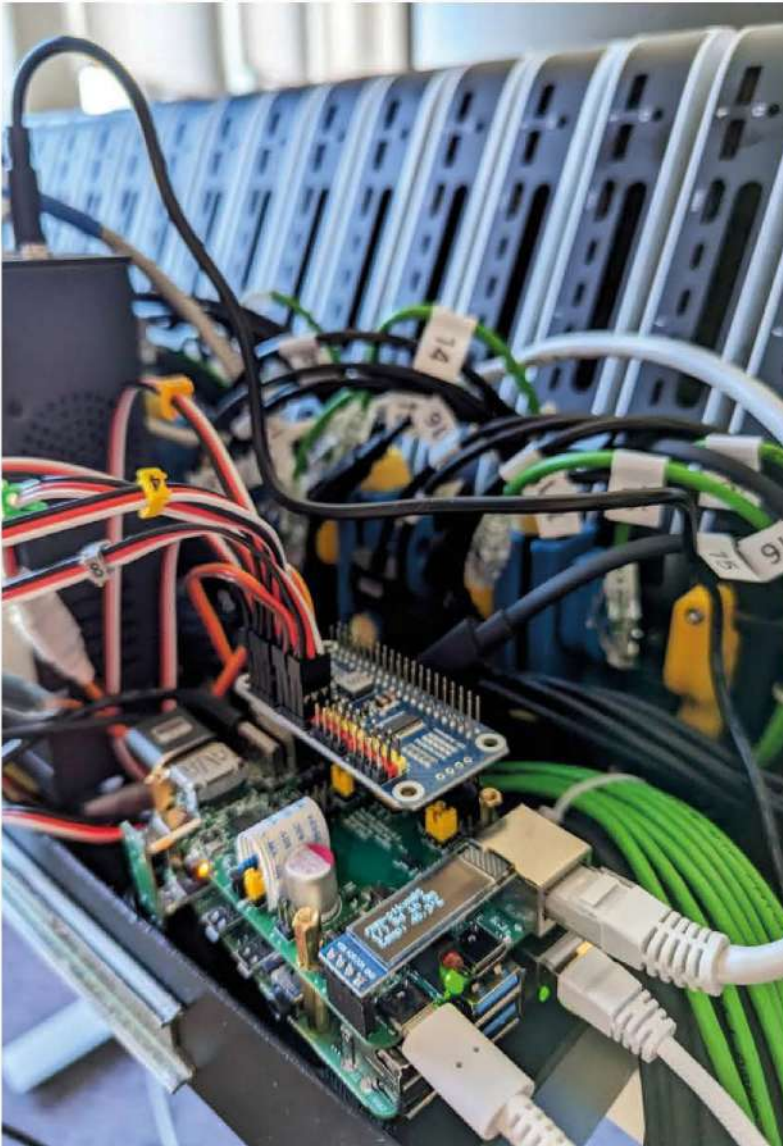
Back to Mac

01 Remotely troubleshooting a Mac mini is hampered by the need to restart it via its power button. Ivan's PiKVM HAT provides a technological solution.

02 PiKVM and a Servo HAT enable Ivan to remotely restart the failed Mac mini for troubleshooting. Raspberry Pi 4 controls the servo that presses the button.

03 One servo is used for every two Mac minis, keeping weight and cost minimal.

PeggyBoard

Climbing walls are already pretty exhilarating but that didn't stop one maker from upgrading his with a Raspberry Pi. **Rob Zwetsloot** gets to grips with it.

MAKER

Pegor Karoglanian

An embedded software engineer who likes to take on a variety of projects in his downtime. His goal is to get others excited to make something.

github.com/ PegorK

Warning!
Build & Climb Safely

If you plan to recreate this project, it should only be attempted by people well versed in building (and climbing safety)

magpi.cc/powertools

▶ Select your route on your phone to activate it on the wall. The web app remembers past routes and lets you create custom ones

During the various lockdowns at the start of COVID, people picked up various hobbies. Baking sourdough bread, setting up a new island in *Animal Crossing*, and getting some home exercise. Instead of deadlifts and HIIT, however, one maker helped a friend out with a special piece of equipment.

"[It's] called the PeggyBoard," Pegor Karoglanian tells us about his creation. "It's an interactive climbing wall powered by a Raspberry Pi that allows the user to set specified routes using a web app which also allows them to save routes or load old ones. It was originally developed when the COVID-19 pandemic first started and the local climbing gym had to shut its doors to follow quarantine protocols. My friend Liam reached out to me and wanted to make a woody [a climbing wall used for training] and asked if I could design something to make it interactive."

This is not a new idea – in fact Pegor mentions a pre-existing product called MoonBoard which he drew inspiration from – however making it becomes part of the fun. Also, it's significantly cheaper too.

❝ The LEDs all light up properly, the web app is easy to use… and the database is very useful to go back to saved climbs ❞

The base is a custom built climbing wall in a garage

A web app lets you choose a route on an internet connected Raspberry Pi, which then lights up the correct LEDs

▼ The LED grid is also painted onto the wall so you know what holds you're selecting
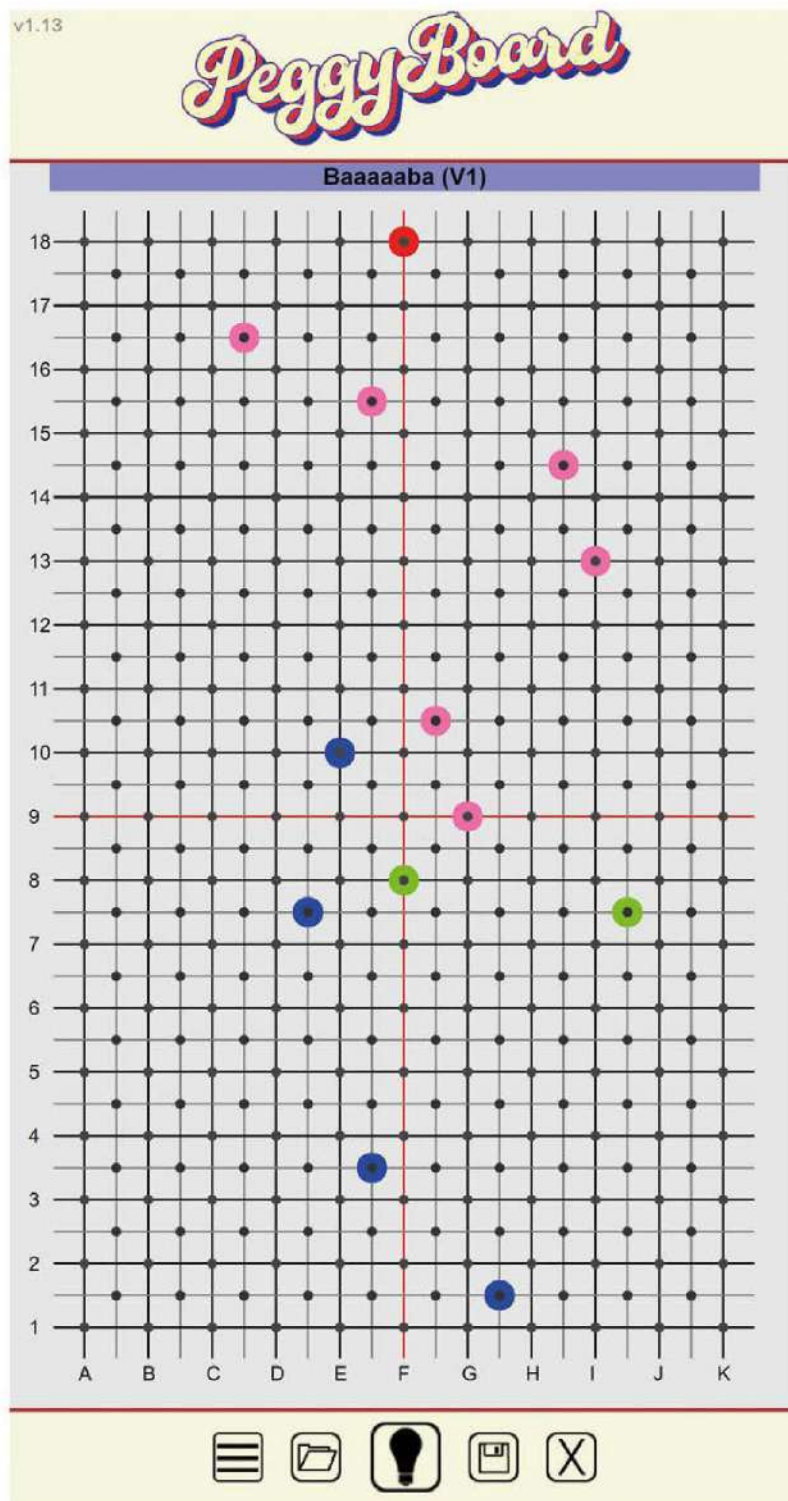
LED walls

Building a high-tech climbing wall might seem daunting, but breaking it down into three parts makes it seem a little less intimidating.

"The first being the building of the physical climbing wall which involved some framing and reinforcing the garage roof," explains Pegor. "The second was putting together the control panel which housed the Raspberry Pi, touchscreen, power supply, and level shifter. The last part was writing the code to make the whole thing interactive and functional. It's mostly written in JavaScript, PHP, shell scripts, HTML, CSS, and Python."

Reinforcing a roof still seems like a bit of a tricky process, but he makes it sound simple when it's broken down that way. It seems to have done the trick though.

"It works great," Pegor says. "The LEDs all light up properly, the web app is easy to use – outside of the occasional fat finger on the wrong hold – and the database is very useful to go back to saved climbs. The only issue we ran into was the occasional Wi-Fi connection drop, but that was due to router issues and the distance of the control panel."

▲ A new addition is a touchscreen control so you don't always need the webapp

▲ A climbing wall should look like one, including the art you'd commonly see in a climbing gym
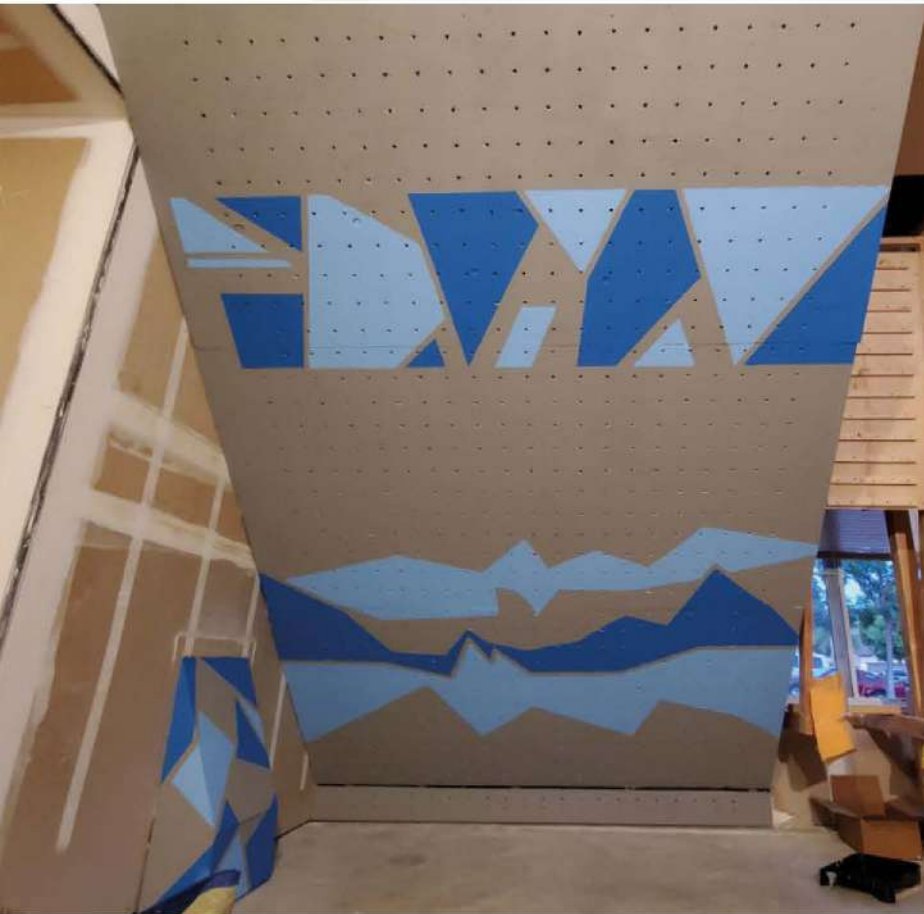
Wall of the future

It's a very interesting setup which would likely lead to good data collection about your climbs – great for people wanting to improve times, or see any mistakes they hadn't noticed. For now, though, this particular wall is largely complete.

"The touchscreen addition was the latest upgrade," Pegor tells us. "It didn't originally have one, and this made configuration a bit of a hassle on first setup or network changes. With that addition I also decided to clean up the code and make it open-source, and here we are. I don't have any future upgrade plans at this time. My friend has made a couple of suggestions for some new fun features, such as lighting up a hold momentarily so it's easier to see which hold you have set, but I haven't set time aside to implement them yet."

Hopefully the garage roof won't need further reinforcement for it.

Custom climb

01 Building a frame for a climbing wall is serious business. It needs to be sturdy enough to support itself and a person – in this case the ceiling and roof had to be reinforced.

02 Adding electronics means a lot of LEDs in this case – which you'll need to power and address specifically to illuminate the chosen route

03 A lot of coding went into PeggyBoard – routes, LED control, web services, and a web app, built using several kinds of technology

YAFC Flux
Capacitor

A classic time travel film prop brought about via Raspberry Pi caught the eye of **Rosie Hattersley**, a sucker for all things 1980s

MAKER

Ambrogio Galbusera

Ambrogio is a keen paraglider and "a true enthusiast who finds joy in the blend of technology, creativity, and the exhilarating freedom of the skies"

magpi.cc/ ambrogio

There's plenty of interest in the 1980s: from *Ghostbusters*, *The Goonies*, to *Back to the Future*; whether riffing on cultural references and storylines a la *Stranger Things* or recreating props and costumes for cosplay and Halloween. In fact, so prevalent are such remakes that creator Ambrogio Galbusera named his Marty McFly and Doc Brown prop YAFC (yet another flux capacitor): **magpi.cc/yafc**.

Ambrogio was keen to create a replica of the iconic flux capacitor that appeared in the *Back to the Future* film series and which Doc Brown reveals to Marty "is what makes time travel possible".

However, he wanted to design something other than the replica props made from LED strips he'd seen online. Bizarrely, the idea to focus on the visual and audio effects of *Back to the Future*'s flux capacitor came to mind when he was frying food and the sizzles triggered a memory.

Time flies

Ambrogio's idea was to reproduce the "energy flow" effect in the flux capacitor by means of a video created with a video editor with which "you are free to create any special effect you may think of". He typically uses VSDC, which he

▶ YAFC Flux Capacitor is largely made from household objects

Different animations are selected via the external buttons and shown on the 7-inch display

Maker Ambrogio created animations simulating the flux capacitor from *Back to the Future*

Raspberry Pi 4 and Pimoroni Automation HAT hidden in a cardboard box display a range of electrifying flux effects
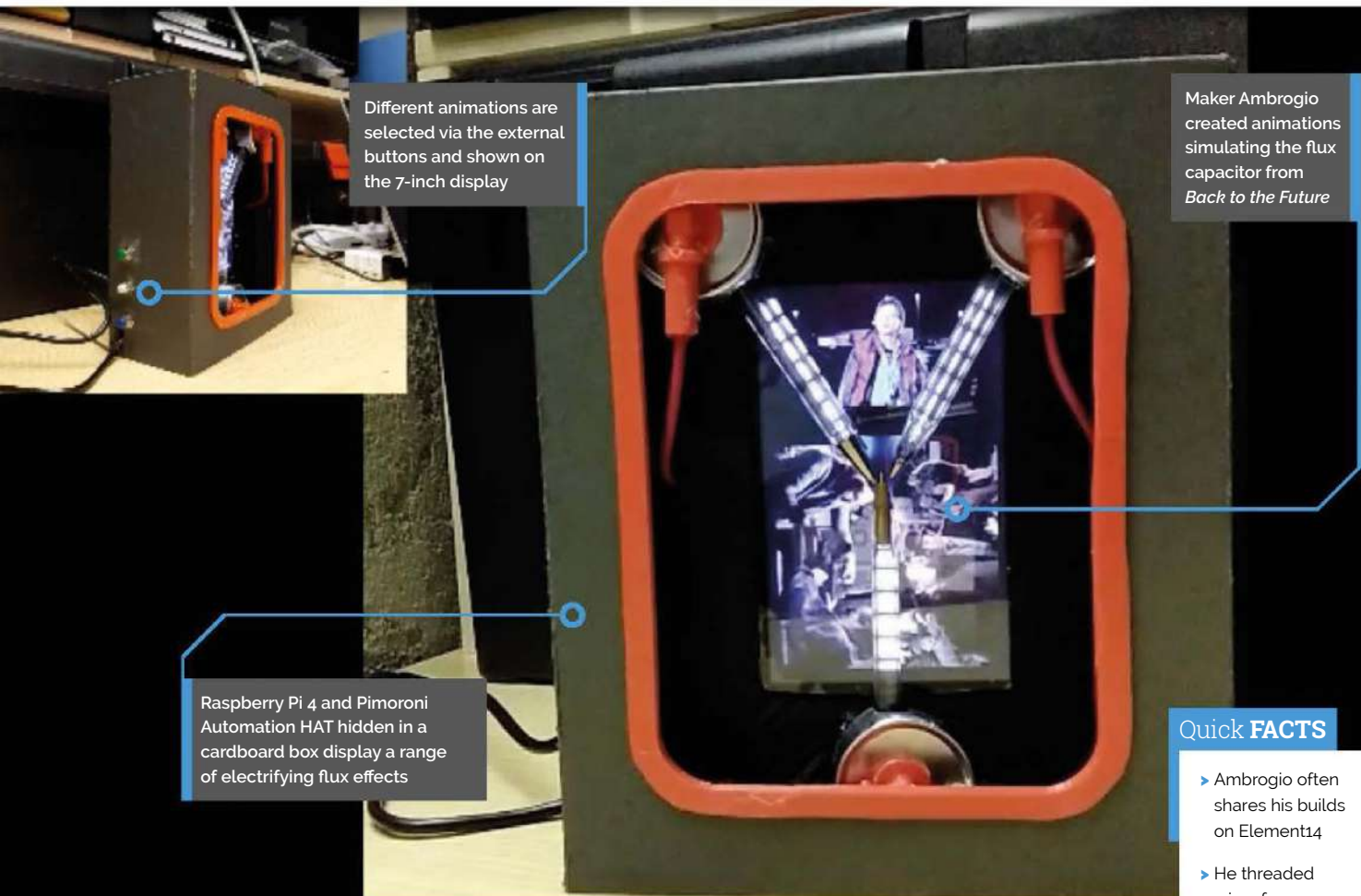
Quick **FACTS**

> Ambrogio often shares his builds on Element14

> He threaded wires from an old multimeter...

> ...through clear pen cases serving as energy conduits...

> ...capped by the bases of tealight candle holders

> Flux effects are triggered by a Pimoroni Automation HAT

▲ A resprayed box and well-chosen animations result in a stunning film prop

▲ Pimoroni's Automation HAT sits atop Raspberry Pi 4

He created an energy flow animation in which three streams all move into the centre

finds an extremely powerful tool despite being free. He created an energy flow animation in which three streams all move into the centre and added a lightning effect by stripping out part of a thunder chroma clip from Pixabay: **magpi.cc/thunderchromakey**.

There are "plenty of LCD screens that connect to Raspberry Pi through its display interface. Not having the extra cabling required by a standard HDMI screen makes the final build more compact and cleaner," Ambrogio reasoned. As a maker, he regards Raspberry Pi as "a must-have, because it gives you all the capabilities of a fully fledged Linux system in a fanless, low-power, tinkerable package". He also notes that Raspberry Pi comes with a preinstalled VLC media player – "a great player that can be controlled from the command

line". This appealed because he wanted to control the volume and the clip being played by means of push buttons. Ambrogio is also a big fan of Python. "From a maker point of view, [Python] is a great language since it does not require complex environment setup."

Reuse and reduce

Alongside Raspberry Pi 4, Ambrogio used a 7-inch LCD display and a Pimoroni Automation HAT mini board. Ambrogio wrote a Python 3 script to read the status of the buttons and control the VLC media player. He also designed and printed some 3D parts. The other components for his YAFC Flux Capacitor were largely assembled from leftovers hanging around in his lab, such as the buttons and wires. He recycled and spray-painted a cardboard

box as a case for the screen, then repurposed candles and used clear plastic pen cases for the lighting and flow effects.

In comparison to Ambrogio's other makes – among them a Rube Goldberg machine to increase your self esteem and an automated crop grower – the YAFC Flux Capacitor project "was not particularly complex", turning out as expected from the outset without the need for multiple iterations. Having tweaked the VLC media player commands, Ambrogio solved everything in maybe a couple of hours, thanks to the great resources available on the web.

The availability of inexpensive displays that work with Raspberry Pi and relatively low overheads for the project makes it fairly easy to replicate. Ambrogio used Raspberry Pi 4, "but even an older version should be fine for this project since there are no strict requirements in terms of computing power. 🄼

▼ A still from *Back to the Future* shows the original flux capacitor

Electrifying effects
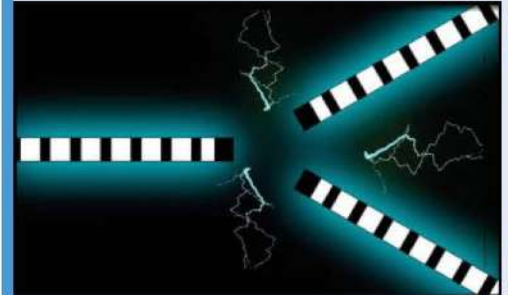
01 Create the video effects you want for the flux capacitor using a video editor and copy them to an SD card. Alternatively, use the video clips Ambrogio shares along with his source code: **magpi.cc/yafcgit**.
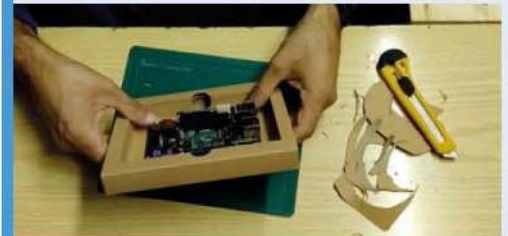
02 Trace around the screen, Raspberry Pi and Automation HAT and cut out a space for them in the cardboard box (decorating it as you wish) then connect to hardware buttons and a power supply.

03 Use ballpoint pen cases, tealight bases and electrical wires to simulate the electrical effects which the video animation shows onscreen.

THEA500 Mini keyboard

THEA500 Mini console is something to write home about if you're an Amiga fan – until you realise you can't use its keys to do so. **David Crookes** discovers a solution.

MAKER

Dean Woodyatt

Dean Woodyatt hails from Wales but now lives near Sydney. Having studied electronics, he describes himself as a tinkerer and a hoarder of any old tech.

magpi.cc/thea500

Fans of Commodore's Amiga range of computers were overjoyed when a miniature version of one of the machines was released in April 2022. THEA500 Mini, as it's called, is a plug-and-play reimagining of the Amiga 500 but, while it's capable of playing thousands of games and comes with a mouse and joypad, there's a little problem with the keyboard. It doesn't work.

Try as you might, you'll never be able to bash those keys because they're a solid, non-moving, unconnected block of plastic. That, however, hasn't prevented one Amiga enthusiast from dreaming of an alternate reality. Rather than plug in an USB keyboard as suggested by THEA500 Mini's manufacturer, Dean Woodyatt has spent a couple of years creating a working keyboard mod. He did the same for THEC64 Mini so he's proving to be a dab hand at such things.

Key to success

It hasn't been easy. THEC64 Mini keyboard mod used an ATMega32U4 microcontroller, but Dean found it didn't have enough inputs to handle all of the small-factor Amiga's keys. "THEA500 Mini has nearly 100 keys and the 32U4 can only comfortably handle 64," he says. "Using the raw 32U4 chip, adding support circuitry and having it assembled to gain access to enough IO to just about handle THEA500 Mini keys was really too difficult and expensive."

Dean also found another issue: "There is very little room inside the case for a keyboard," he says. As such, he needed to find a simple, small solution and decided to make use of Raspberry Pi Pico. "It really makes THEA500 Mini keyboard possible," Dean explains. "It has enough IO to make a 10 x 10 keyboard matrix possible, it's super-cheap and it's been widely available despite all the component shortages.

"Raspberry Pi Pico is also super slim and it allows a keyboard to fit inside THEA500 Mini by making only one small change to the case. I'm

▲ The keys were twisting out of alignment, and Dean found oval switches were the best solution

acutely aware that people hate to take a pair of snips to their devices, but this cuts away a small support inside that can't be seen. Only a few millimetres need to be shaved off."

If the cap fits

To create the keyboard, Dean made a schematic and designed the PCB and component footprints using the web-based tool EasyEDA, onto which key switches and locking mechanisms were placed. He also designed and 3D printed a set of keycaps, being sure to make them look and feel as authentically Amiga-like as possible. He even included a light beneath the Caps Lock key.

> ❝ There is very little room inside the case for a keyboard ❞

"For the keycaps, I learned how to use a resin printer and, because no one manufactures resin in the right shades of brown and beige to match the Commodore computers, I spent a few months researching how to colour resin," Dean says.

With that done, it's a matter of connecting the PCB to Raspberry Pi Pico and hooking up to THEA500 Mini motherboard. "I'm using a fantastic

▼ The original non-working THE A500 Mini keys were too tall and densely packed – the gap between them is just 0.245mm so Dean made his own set
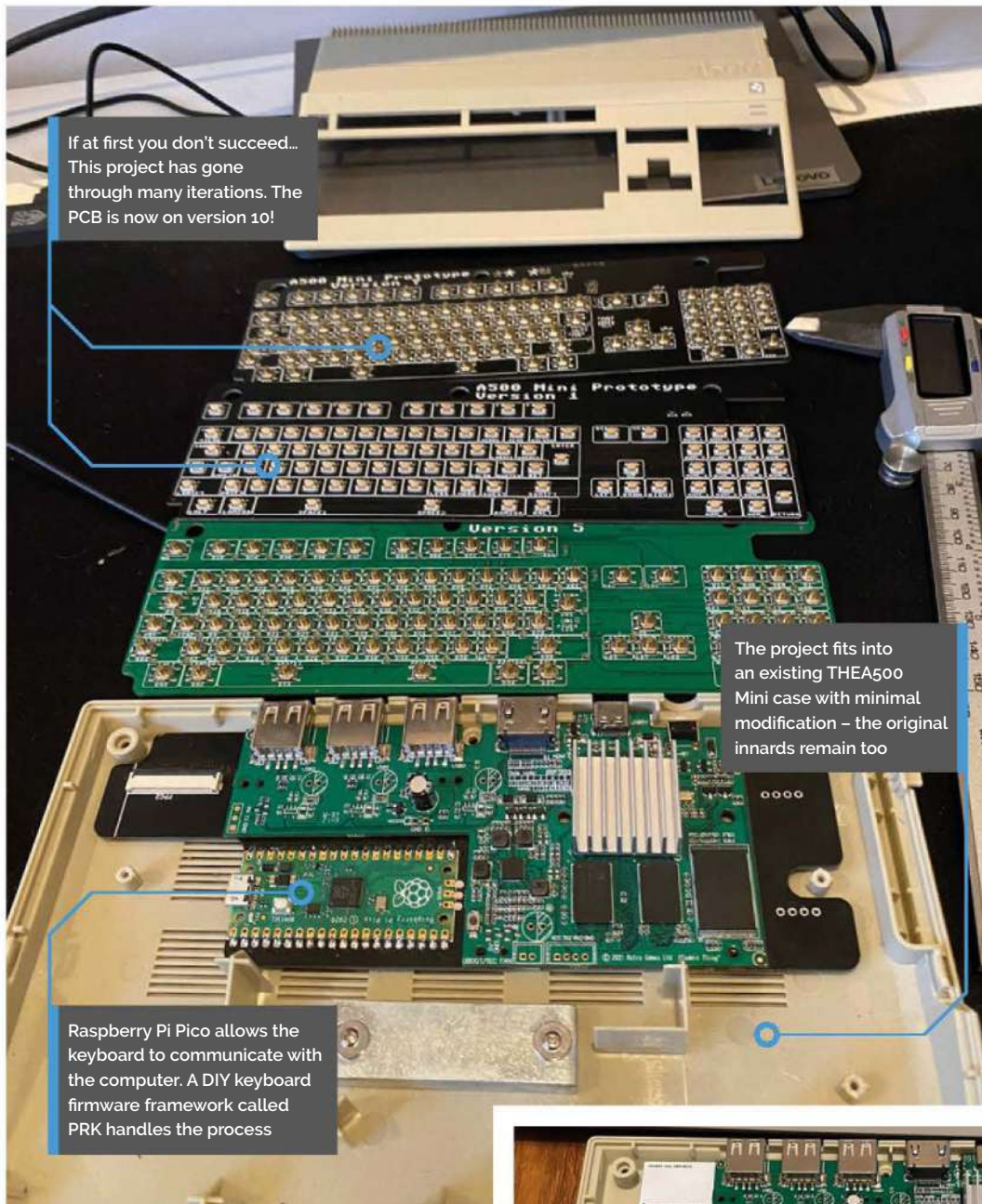
If at first you don't succeed… This project has gone through many iterations. The PCB is now on version 10!

The project fits into an existing THEA500 Mini case with minimal modification – the original innards remain too

Raspberry Pi Pico allows the keyboard to communicate with the computer. A DIY keyboard firmware framework called PRK handles the process

▼ This is where it all began. As an in-joke, the keyboard has n-key rollover – accidentally press multiple mini keys simultaneously and all keypresses will the registered

firmware called PRK which allows you to simply drag and drop a text file containing the keyboard map over to Raspberry Pi Pico," Dean says. The hard work, however, continues.

"The project is about 80% finished, and the final 20% is iterating small parts to make it easier and cheaper to manufacture," he adds. As for the motivation, well that's something many retro enthusiasts will understand: "I do all this stuff mainly for me," he confesses. "I'm really just channelling my teenage self, and using my learned skills to do stuff I figured would be cool back then." M

3D Laser Radar

Scanning items with lasers creates interesting photographs.
Rob Zwetsloot scans the results with his eyes.

Gavin Chang

An engineer at WIZnet who likes IoT and using it to solve problems in life.

magpi.cc/ gavinchang

⚠️

Warning!
Laser pointer

Be careful when using laser pointers in your projects and don't aim a laser pointer at a person's head.

magpi.cc/lasersafety

▶ The heart object is visible on the screen – due to the way the laser pans, the edges are technically farther away

There are many ways to 3D scan objects, all of which seem to have been done with Raspberry Pi at some point. They're usually done to create 3D scans, however WIZnet engineer Gavin Chang is doing something a little different with laser scanning.

"I wanted to make a radar application based on a two-degrees of freedom laser module," Gavin tells us. "Through the actions of two servos, the laser module can scan in 3D to form distance information of all points in a space. This can be rendered through an algorithm to form a photograph, and the information is then sent to the display hardware 'Cloud Pixel' through the network to show the measurement results."

The images it produces are pretty cool and abstract, using a sort of heat map overlay to separate the layers of the object being scanned to recreate the object. It's built with RP2040 and RP2040-powered devices at its core, which Gavin chose because of the great support. He used it to create the scanning rig called Cloud Motion and also the Cloud Pixel display. He seems pretty proud of making everything out of RP2040 and having them talk via Ethernet or Wi-Fi.
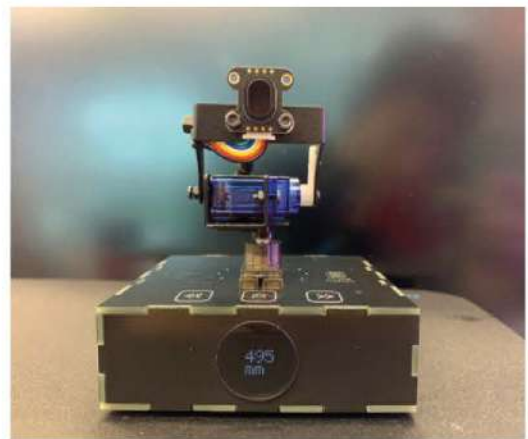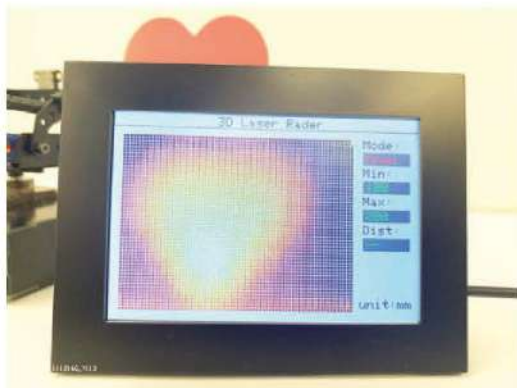
▲ The laser sensor can pan and tilt, and can be controlled manually to get a standard distance read out

Laser is an acronym

Having developed some parts of the Laser Radar already, this ended up just being the first use of the components.

"My project development process always starts with a hardware platform, and then I develop corresponding projects based on the hardware platform," Gavin explains. "This time for 3D Laser Radar, I first made the Cloud Motion hardware, and then used 3D Laser Radar as the first project using this hardware. As hardware with networking and servos, I think there are many applications suitable for it. For example, I can change the laser sensor to an infrared imaging sensor, which can be set to always look at the point with the highest temperature in a given space using the servos."

Lase is a verb

Overall Gavin seems pretty happy with how the project turned out – at the very least it does what he set out to do. He does have a few things he'd like to improve though: "First, because
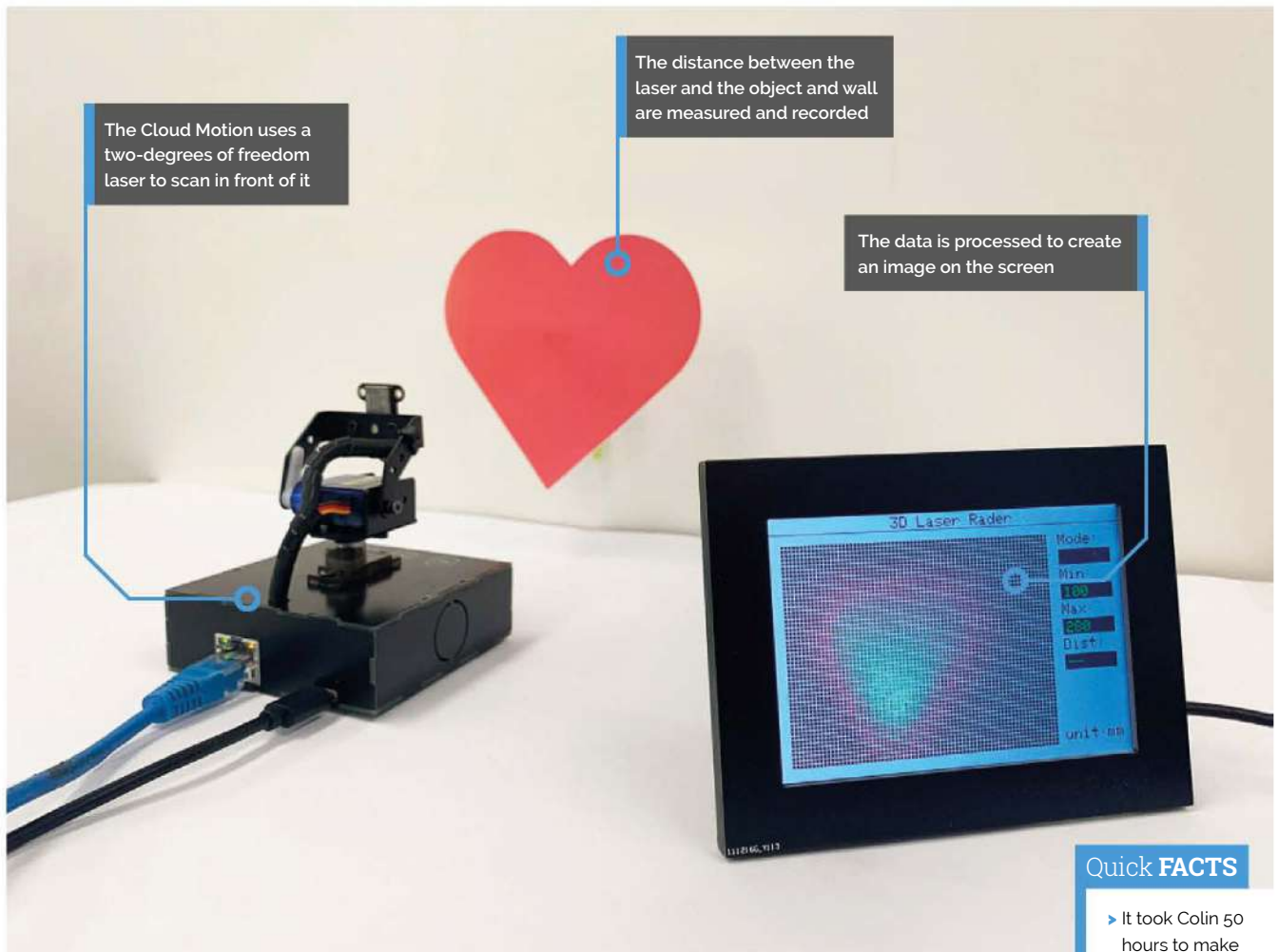
The Cloud Motion uses a two-degrees of freedom laser to scan in front of it

The distance between the laser and the object and wall are measured and recorded

The data is processed to create an image on the screen

> ❝ My project development process always starts with a hardware platform, and then I develop corresponding projects based on the hardware platform ❞

there are many points that need to be scanned, and each point requires a servo to operate, it takes a long time to complete the scan," Gavin says. "My next improvement direction will be to speed up the scanning speed and shorten the scanning time. Secondly, after the scanning is completed, I use Cloud Pixel for display. The image algorithm needs to be optimized so that the outline of the target object can be displayed more accurately."

We'd be interested to see how a sharp 3D-scan-to-photo would be, but for now we quite like the fuzzy edges.

Quick **FACTS**

> It took Colin 50 hours to make

> He 3D-printed the chassis at his local Tesco Express

> The batteries can last eight hours at full power

> It cost £55 in parts from CPC

> Colin used xyz resources to learn techniques (**xyz.com**)

◄ It can detect the curves in objects such as cans
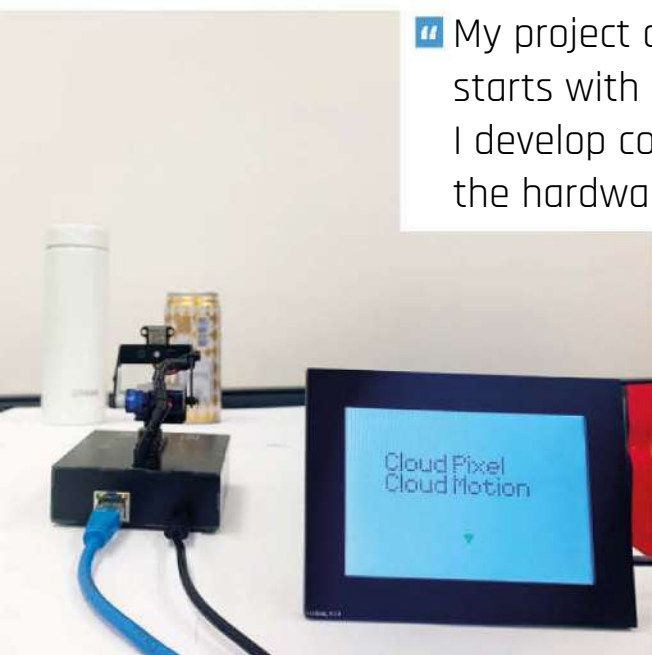
SNES XL

BFG means Big Friendly Gamer. By **Ashley Whittaker**

MAKER

Arnov Sharma

Arnov is a microcontroller enthusiast and a maker from India.

magpi.cc/ arnovsharmer

SNES XL is a gigantic Super Nintendo controller built by Arnov Sharma. It has functioning buttons and Raspberry Pi hidden inside, so you can play retro games and pretend you're a Borrower at the same time.

Button management

Every button on SNES XL controller has its own custom PCB, created using PCBWay (**pcbway.com**) an online service for producing PCB prototypes. Each board is shown fully working by Arnov on YouTube (**magpi.cc/snesxlyt**). Tactile switches on the custom boards are positioned just below the 3D-printed buttons, such that pressing a button toggles its switch. Each of the switches is wired up to a pin on a XIAO SAMD21 (**magpi.cc/samd21**) development board from Seeed Studio (see **Figure 1**). When SNES XL is connected to a computer (in this case Raspberry Pi 4), the Seeed XIAO appears as a gaming controller icon and can be selected for gameplay.

Too big to print or hold

Arnov designed the controller housing in Fusion360. It had to be 3D printed in three separate parts due to its size, before being superglued together. More videos and images can be found on Arnov's Instructables (**magpi.cc/snesxlinst**).

Retro game emulation here comes courtesy of Recalbox (**recalbox.com**). Power Pi, a Raspberry Pi dock/enclosure with an integrated lithium cell battery pack that Arnov also designed, provides power.

Arnov has to set the controller flat on the

▲ The SNES XL is fully working (although hard to hold). Here, Arnov is using it to play a game of Doom!

▶ **Figure 1:** The buttons are switches wired up to a pin on a Seeed XIAO SAMD21 board
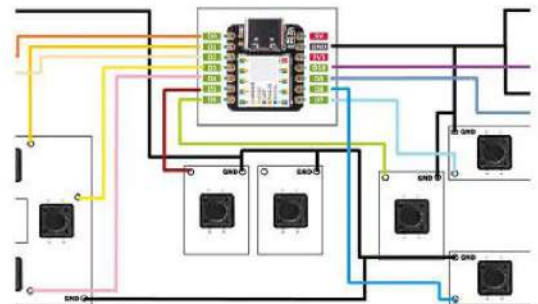
Arnov's SNES XL is a gigantic 3D-printed game controller that is fully functional

Each button has a custom PCB (printed circuit board) that enables them to be pushed

The controller is connected to Raspberry Pi and playing an open-source version of *Doom*!

Quick **FACTS**

> The buttons are 12 × 12 mm switches

> While the case is 3D printed...

> ... Each button has its own PCB

> The D-PAD is four PCBs

> The PCBs were created with PCBWay

" It had to be 3D printed in three separate parts due to its size "

◄ Inside the giant 3D-printed case

table to play games, because it's too big to hold comfortably. Our favourite Raspberry Pi builds are the ones that are so absurd they turn out to be unusable for their originally intended purpose. The BFG would have no problem, but we're still not sure if he's real or not. We've let Nessie and Bigfoot go, but we're hanging onto our oversized childhood friend.

Gamer geek

Arnov has graced us with his Raspberry Pi-powered gaming kit twice before. The first time was with SANDWICH DOT IO (**magpi.cc/sandwichdot**), an
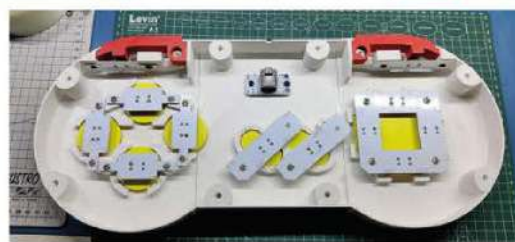
all-in-one desktop gaming system based around Raspberry Pi 3B+ and featuring on-board power as well as a dedicated cooling layer.

PALPi (**magpi.cc/palpi**), a handheld games console with a retro aesthetic that's powered by Raspberry Pi Zero W, is another of Arnov's creations. Let's start taking bets on what he builds next. We're thinking he might go to the other end of the size spectrum and come up with something miniature. Maybe a teeny, tiny, thimble-sized Wii controller for dainty indoor tennis and golf.

PicoZX Handheld

Build your own handheld ZX Spectrum
with Raspberry Pi Pico. By **Ashley Whittaker**

MAKER

Ken St. Cyr

Ken is an
electronics
enthusiast, and
lifelong technology
tinkerer. Be sure
to visit his popular
YouTube channel.

**magpi.cc/
whatskenmaking**

Warning!
Solder

This project requires
soldering. Brush up on
your soldering safety
before starting on it.

magpi.cc/soldering

Ken St. Cyr from the excellent YouTube
channel What's Ken Making isn't quite
over having to spend his childhood in the
US where Sir Clive Sinclair's ZX Spectrum wasn't
available. Fast forward a few years, and Ken has
enough bits and pieces in his workshop to make
pretty much any computer he damn well wants.
Well, he can emulate any computer, anyway.

Peter Misenko (Bobricius to his friends on GitHub,
magpi.cc/bobriciusgit and YouTube, **magpi.cc/
bobriciusyt**) is the brain behind the original design
for PicoZX (**magpi.cc/picozx**), and PicoZX Handheld
(**magpi.cc/picozxhandheld**) – the Raspberry Pi Pico-
based Spectrum emulator that inspired Ken.

> " You'll have 1980s nostalgia
> coming out of your ears
> after a couple of hours
> with this thing "

Peter's short and snappy demo video
(**magpi.cc/picozxyt**) explains the project, but Ken's
longer build video (**magpi.cc/picozxken**), goes into
more detail on how he made his version.

Reason number one why I personally would argue
[*are you sure you want to do this – Ed.*] that PicoZX
might be even better than the original ZX Spectrum:
it exists in the now. Reason number two: it's cuter
because it's smaller, meaning you can also use it as a
handheld device and carry it around in your pocket.
Reason number three: it's built on Raspberry Pi Pico.

Seeing as Sinclair was a pioneer of affordable
home computing with the ZX Spectrum, it's pretty
cool to see a modern-day emulator running on a
microcontroller which costs just $4/£4.

How is it made?

PicoZX is made up of several custom PCBs, but the
Pico and most of the device's parts are soldered
onto one main board. There's also a faceplate,
which is largely cosmetic and holds everything
in place nicely, and a backplate, which holds the
battery and the charge controller. The other four
PCBs frame the device around its edges, leaving
openings for the microSD card and USB ports.

A 2.8-inch IPS display soldered directly onto the
main PCB is the screen for the device. Fifty 7mm
tactile switches give the tiny QWERTY keyboard its
clickety tactility. PicoZX can also be used with a
joystick; Ken showcases an Atari 2600 joystick in
his build video.

▲ Ken's version of the PicoZX Handheld in eye-catching black

The 2.8-inch display enables you to rediscover ZX Spectrum software on the move.

Here is Peter's original white version of PicoZX Handheld

The keyboard has original ZX-style keys with shortcuts for all the BASIC commands printed next to them

Quick **FACTS**

> Pico ZX emulates a Spectrum 128K

> It has VGA output...

> ...while Pico ZX Handheld has a 2.8-inch screen

> Both have a ZX-style keyboard

> You can buy it on Tindie for $16

How does it work?

The Raspberry Pi Pico runs Fruit-Bat's ZX Spectrum emulator (**magpi.cc/fruitbat**) and Jean-Marc Harvengt's Multi-Computer Machine Emulator (M.CU.M.E, **magpi.cc/mcume**). So not only do you have all of the original ZX Spectrum programs at your fingertips, but you can also emulate other devices – such as the Commodore 64, Atari 2600, and ColecoVision – all in one compact handheld device. You'll have 1980s nostalgia coming out of your ears after a couple of hours with this thing.

◄ Components being soldered onto the PicoZX Board

▼ The rear of PicoZX shows an array of output ports

Remembering Clive Sinclair

I'd wager you're an admirer of Sir Clive Sinclair, the inventor of the ZX Spectrum, who died in 2021. Raspberry Pi co-founder Liz Upton wrote a short but sweet note (**magpi.cc/sirclive**) on the day we heard the news, and the comments section quickly filled with stories from people who had been inspired by his work. Have a look if you'd like to take a scroll down memory lane. M

Velo AI

This smart bike light with road monitoring relies on Raspberry Pi's capable low-power compute. By **Phil King**

Low-cost, low-power, compact and performant, Raspberry Pi Compute Module 4 is at the heart of Velo AI's (velo.ai) debut road safety product, which alerts cyclists to vehicle movements behind them.

With a core mission to improve safety for all forms of mobility through the use of smart technology, Pittsburgh-based Velo AI was co-founded by robotics expert Clarke Haynes and AI specialist Micol Marchetti-Bowick. Both have a background in autonomous vehicle technology for the likes of Uber, and sought to apply similar AI algorithms to assist cyclists. Completing the core team is Alison Treaster, who is leading commercial partnership and community-building efforts for the startup firm.

Velo AI's debut product is Copilot, an AI-powered bike light and camera. Based around

Raspberry Pi Compute Module 4, it can detect and distinguish nearby vehicles, understand when one is about to overtake, and identify an aggressive or distracted driver approaching dangerously – in which case, it issues audible and visual alerts for the cyclist and driver to help prevent dangerous situations and crashes.

The challenge

Aware of the limitations of existing bike cameras and vehicle detection devices, the Velo AI team sought to create a more sophisticated AI-based alternative to improve road safety for cyclists.

As an example, says Haynes, a radar-based device such as the Garmin Varia "can't figure out if it's a car behind you or a bus. And to a cyclist, there's a big difference in being passed by a Toyota Corolla versus being passed by a large municipal bus". In addition, he points out, radar only measures radially: "Radars can tell you if something is approaching you, but they can't tell you if something is going to pass you with ten feet of space or one foot of space."

In moving from radar to a camera-based solution, the aim was to create a device that could tell the cyclist "a lot more about what's going on in the world and do a lot of things that the radar can't do". The device would need to help cyclists by providing situational awareness and alerts about nearby vehicles. This includes the ability to distinguish, using computer vision algorithms, between different vehicle types, as well as to estimate their relative speed and to identify and predict driver behaviour.

The first step of developing Copilot's AI algorithms was to collect a large amount of data from riding around a variety of road types, with a focus on interactions with vehicles. This process was aided by a beta-testing cohort of Pittsburgh cyclists – ranging from commuters to recreational riders – who were given a free prototype unit to test.

While the Velo AI team has extensive experience in the field of autonomous vehicles, there was a steep learning curve involved in creating and selling a brand new physical product. "Jumping in and figuring out what it takes to put together a hardware product has been a huge challenge for us," admits Haynes. "So, OK, what's the weatherproofness of this? How do we design a lens to focus light for a bike light?"

A major challenge lay in cramming the camera, LEDs, electronics, and battery pack into a compact and lightweight package. The device also needed to be powerful enough to run AI neural networks, yet with a relatively low power drain to enable it to be used for longer bike rides.

The solution

Raspberry Pi Compute Module 4 is in effect the brain of the Copilot, aided by a custom Hailo AI co-processor to run the neural networks required for the device's computer vision. A fixed-lens Arducam camera is used to record video footage.

The Copilot is supplied with a mount to fix it to a bike's seat post or saddle rail, with the camera facing rearward. The AI analyses the live video footage and, depending on the type of driver behaviour detected, custom alerts may be triggered – audible for the cyclist, and flashing LED light patterns to alert the driver behind.

Three main categories of vehicle behaviour are detected (**magpi.cc/copilotyt**) and used to trigger different alerts. 'Following' behaviour is "when a vehicle is following behind you, but not accelerating toward you," explains Marchetti-Bowick. 'Approaching' is when a vehicle is

> **"** It can detect and distinguish nearby vehicles, understand when one is about to overtake, and identify an aggressive or distracted driver approaching dangerously **"**

accelerating relative to you: "It's getting closer to you… and that can either be directly behind you, or it can be in an adjacent lane to you." The third category is 'overtaking': "That's when we think the vehicle is imminently going to pass you. And that's probably the one you want to be most aware of, because that's the closest proximity interaction that they'll have with you as a cyclist."

In addition, the device connects to a companion app on a smartphone which can be mounted on the bike's handlebars to show the rider a simplified road view with the positions of nearby vehicles. The app also enables the user to download video footage of their rides.

Power to the unit is supplied by a rechargeable two-cell lithium-ion battery. With the Copilot consuming a mere 4–5 watts of power, that equates to around five hours of battery life.

Why Raspberry Pi?

The team experimented early on with Nvidia Jetson boards for the prototype Copilot, but found that they were too expensive and their GPUs too power-hungry, according to Haynes. "If you're going to run GPUs full tilt, you're talking about something that even in a Jetson… you're going 10 to 20 watts. And then to have a battery to power something
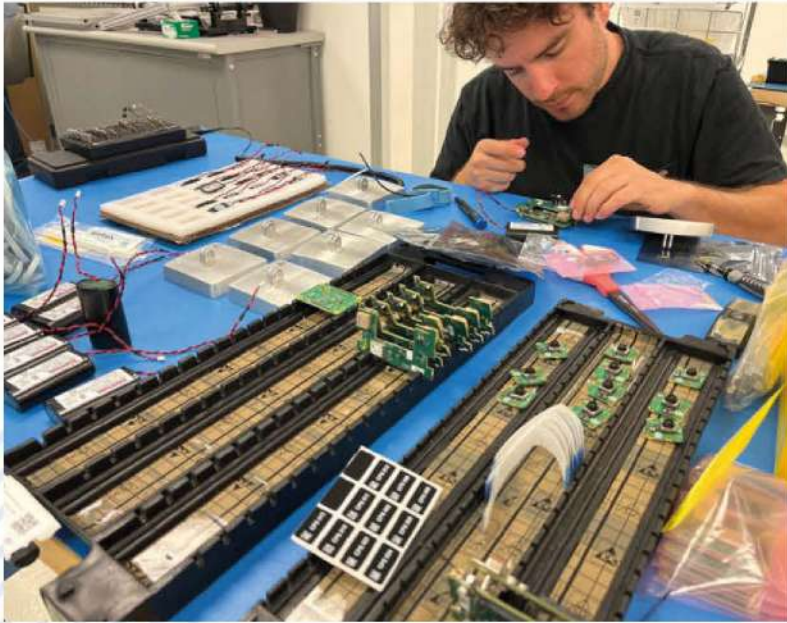
that's going at 10 watts for many hours, because we want people to go for four- or five-hour bike rides with this, it was just too much heat, too much weight [due to a larger battery pack being required]. And that's what really led us to the Raspberry Pi."

The very first circuit board, before Velo AI partnered with contract manufacturer and Raspberry Pi Design Partner Hellbender (**magpi.cc/designpartners**), was very simple: "We plugged in the CM4 one side, we slotted in the M.2 Hailo on the other side, and then connected the camera. And we had everything we needed to just prove that the compute stack worked. Since then, it's advanced more and more. But the mere fact that the CM4 is a separate discrete component that just works; we can use everything that's on it, including the Wi-Fi and Bluetooth. That's great for us to just get started."

The search for running the AI with super-low power consumption led them to add a Hailo AI co-processor: "The combination of Raspberry Pi plus Hailo made things super-easy to prototype and develop," says Haynes.

The results

The Copilot appeals to different types of cyclists, says Treaster. "There's not a particular customer persona, but they want to support making streets safer because they're using streets as a cyclist often." Potential customers also include parents and spouses who care about the cyclist in their life and want something that's going to keep them safer on the road. "We've had a lot of folks say, 'I would buy this for my son or daughter, I would buy this for my husband'."

With the added awareness it provides, the device has already become an essential aid for some cyclists, says Haynes. "We've got great feedback from early customers that they don't like having to ride their bike without it on there."

The team hopes that Copilot may have broader social benefits. "The number one reason people don't bike more is they don't feel safe," notes Haynes. "And so our goal was, let's get more people to bike, and let's get them to bike more because they feel safe."

A major bonus is that data gathered from Copilot devices can prove useful to aid local authorities and road safety organisations seeking to make cities and towns safer for cycling. "We are in the middle of starting a partnership with the city of Pittsburgh," says Haynes, "where we're going to deploy dozens of these Copilots with people that bike to work and use that to actually inform where do we need to improve the bike infrastructure?"

Another pilot scheme is planned for Roanoke, Virginia, reveals Treaster. "They are working on the Vision Zero campaign [with the eventual aim of zero deaths for pedestrians and cyclists]. And they said it would be great to be able to get any kind of data that's specific to cycling before the legislation is passed to say we need to give cyclists three feet of space when passing." Post-legislation data can then be analysed to see how it has affected driver behaviour.

"We're absolutely interested in as much as we can do to get these devices out there and use this data to make cycling safer," adds Haynes.
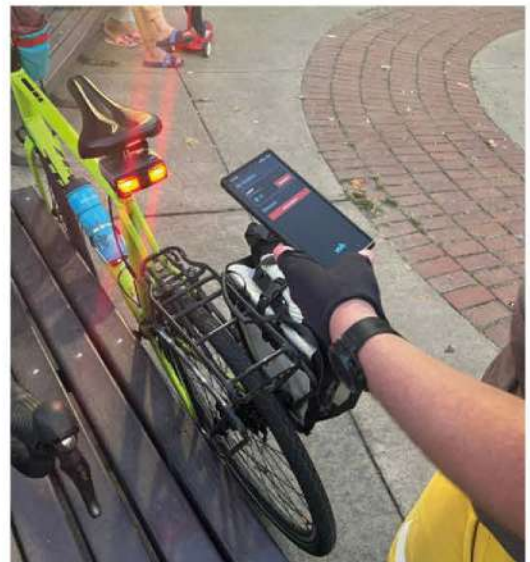
Industrial Shields

The industrial ninja.
Efficient. Reliable... and
Powered by **Raspberry Pi.**

Check out our PLCs, Panel PCs & UPS range at
www.industrialshields.com

RASPBERRY PI TROUBLESHOOTING GUIDE 2024

Even the greatest friends can be frustrating sometimes. **PJ Evans** sits you down, hands you a tissue and asks how he can help

With a new model of Raspberry Pi comes change. The advancement of this little computer's amazing capabilities bring necessary changes to its operating system and in turn compatibility with older (and sometimes current) software and hardware. Since our original troubleshooting guide (*The MagPi* issue #60: **magpi.cc/60**), there's a lot that has changed and it's only right that we revisit the guide and bring it up to date for the newest member of the family: Raspberry Pi 5. So, if you're confused, perplexed or downright frustrated with a Raspberry Pi project, maybe some words of wisdom (or at least a clue) can be found in these pages.
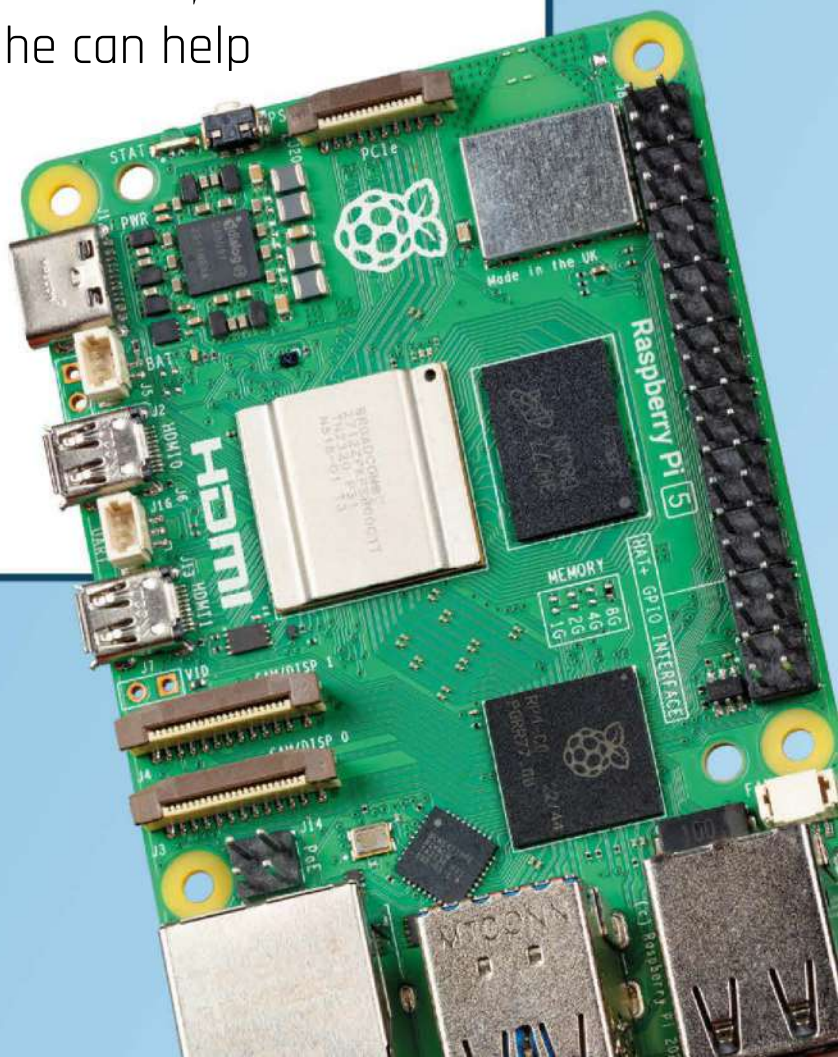
My Raspberry Pi will not power on!

Raspberry Pi gone a bit nihilist? No life to be found? It can be more than a little alarming when you plug in your new project and… nothing. Here's a list of things you can try to get to the bottom of the problem. Sometimes it can be a real d'oh moment, sometimes there's more to it.

Check the power supply

We've all done it (in this writer's case, many, many times). Have you plugged the power supply into Raspberry Pi and the mains? Have you switched the socket on? If the answer is yes, start by checking the supply itself. Can you swap it out for a known-good supply and try again? If not, try charging a compatible USB device and see if you confirm it is working. If you have another Raspberry Pi to hand, check whether the power supply can power it. If you, so can eliminate it from your enquiries.

> **❝** It can be more than a little alarming when you plug in your new project and… nothin **❞**

Use the right power supply

If you're not getting any light on the Raspberry Pi itself, again the supply may be faulty. If it has an untethered cable, check the cable itself is alright.

The best choice of all is to have an official Raspberry Pi power supply. These have a slightly higher power output than regular USB power supplies, which promotes more stable operation. Read more at **magpi.cc/power**.

Any signs of life?

When you apply power, do you see any LED activity on the board itself? All Raspberry Pi boards have at least one LED designed to indicate status. The red LED indicates power. If you do not see any red light at all when you apply power, and you've proven your power supply is OK, then you may have a serious problem with your Raspberry Pi. If it flashes, power has been detected, but not enough to safely boot the machine. A solid red LED means power is OK (well, kind of – again we'll get to that, see 'Lightning strikes') and the system will attempt to boot.

▲ Red LED in the morning, boot failure warning

The green, green flash of boot

Within a second or two of the red light appearing, a green one should appear. On some Raspberry Pi boards this is a separate LED, on others the same. Green indicates the microSD card is being accessed. On a normal boot, the light will flash at irregular intervals as the card is accessed. However, if the LED starts pulsing in a regular pattern, there is an issue with the operating system or the SD card itself. Consider trying a different microSD card if possible. **See magpi.cc/flashcodes**.

A pair of boots

A final check. There is a microSD card inserted, isn't there? Again, we've all done it. Check not only that there is a card in place but that it's snugly inserted. Is the Raspberry Pi configured to only boot from USB or an M.2 device? (See **magpi.cc/raspiconfig**). If so, reflash to move back to microSD card booting. You can use Raspberry Pi Imager (**magpi.cc/imager**) to do this.

Power, but nothing else
What to do when the operating system won't play ball

Let's assume by this point you have a Raspberry Pi that is powering up and showing activity, but you can't get to the desktop or a command prompt. The first thing we need to do is ensure the microSD card is okay, and you have the right operating system.

> " The first thing we need to do is ensure the microSD card is okay "

There's no video

If you've got this far then you'll have a booting Raspberry Pi but possibly no video. Time to start with the (seemingly) obvious. Is the HDMI cable plugged in at both ends? Is it known to work? Is the monitor's source correctly set? Is the monitor on? In some circumstances, plugging in a monitor or TV after boot has started will result in no video output (as the Raspberry Pi has no opportunity to check capabilities). Make sure the monitor is on, and set to the correct source, and the cable plugged in both ends, then boot your Raspberry Pi. If you have another HDMI device, try that too, to

establish where the issue is. You might also need to try the other HDMI port if you have a newer model.

Not all cards are alike

Buy from a brand or vendor you trust. That £10 1TB microSD card may be cheap, but it's unlikely to be reliable (or even 1TB). A rule of thumb is to pick the smallest capacity card for the job. Don't buy a 1TB card when 32GB will do. Smaller capacities have been manufactured longer with less cramped components, and are likely to be much more reliable.

There is a bewildering array of standards you'll see around microSD cards, but the important one is its class. Ideally you want a Class 10 card for your Raspberry Pi. Buy from a Raspberry Pi Approved Reseller (**magpi.cc/resellers**).

Operation!

A reliable card needs the right operating system. Luckily, a recent update to Raspberry Pi Imager (**magpi.cc/imager**) has made this easier than ever. Imager now asks you which Raspberry Pi you are using and will then only show you compatible images. You literally cannot go wrong (but make sure you've identified your Raspberry Pi – the model name is always etched on the PCB).

Following these two steps will ensure you always have the right SD card and the right operating system. Now you hopefully have a booting system, so let's look at what else can cause a furrowed brow and a raised eyebrow.

▲ If you see this, you need more power!
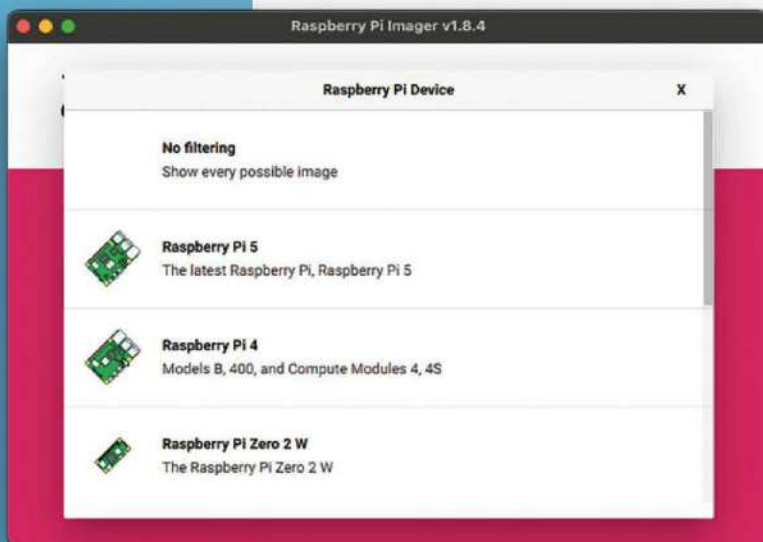
Low voltage

When using your Raspberry Pi if you get a "low voltage warning" in the top-right you have a power problem. This is typically caused by using a non-standard power supply (such as a mobile phone charger) to power your Raspberry Pi. The operating system reacts by throttling the CPU speed so less power is required, slowing your machine down. In some cases, your Raspberry Pi may power down altogether. Using the wrong supply can permanently damage your Raspberry Pi. Get an official power supply (**magpi.cc/powersupply**).

If you need composite output, this new header is where to find it

HDM-why?
How to get your display looking sharp

Ok, so we've booted, power's good, but the picture is terrible. What's going on? If you're seeing a fuzzy but stable image, there's probably been a bit of an argument between the Raspberry Pi HDMI circuitry and the connected monitor, especially if it is a TV. Some TVs lie to connected devices about their true capability, often advertising a 1080p resolution when the truth is nearer 1280 × 768. You have to force the resolution at boot time by modifying **/boot/config.txt**.

Where's the composite connector?

If you're looking to get composite video out of a Raspberry Pi, maybe for your retro gaming project, you may see that the combined audio/video socket on earlier models has disappeared entirely on Raspberry Pi 5. However, you can still get composite video out by soldering a header to J7, next to HDMI 1. If you don't get an image, make sure composite output is enabled using `raspi-config` from the command line.

Other video options

If you need a DVI connection for video, these are directly compatible with HDMI, so you just need the right cable and nothing else. VGA is possible, but you will need a USB adaptor. Make sure you check for compatibility first, as not all will work with Raspberry Pi.
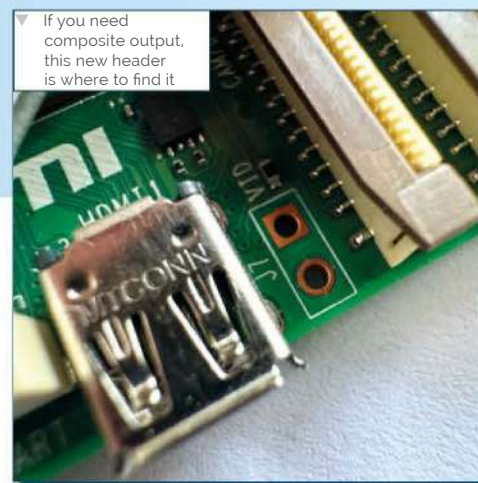
Audio aggro
Audio has never been straightforward on Linux-based systems but the new PipeWire system is the best yet

Audio has changed with the new Raspberry Pi 5 boards. Although the classic ALSA audio system is still present, in the desktop environment the previous PulseAudio system has been replaced by PipeWire. If you're enjoying the sound of silence a little too much, here are some things you should know.

Where do I plug my headphones in?

Raspberry Pi 5 uses its two HDMI sockets as primary audio and video output. The audio/video socket present on previous models has been removed. You can still get composite video output from the J7 header on the board, but for audio you will need an inexpensive USB audio adaptor. This will also have the bonus of audio input so you can record through it.

There's no sound from my HDMI

Firstly, does the monitor or TV you've connected up support it? If your montitor lacks sound, either

> **"** Raspberry Pi 5 uses its two HDMI sockets as primary audio and video output **"**

add a USB-based audio adapter or use a HDMI breakout box, which can output the audio to a headphone jack or RCA connectors.

I want to build a media centre

There are a world of compatible DAC (digital-analogue convertor) audio HATs which provide much superior sound quality. There's the official model or a wide range of audiophile choices with an even wider range of price. Even the budget HATs will provide much better analogue sound output than the Raspberry Pi alone. Check *The MagPi* #117 (**magpi.cc/117**) for tips on improving audio.

Sound controls look the same, but a new improved back-end controls the audio
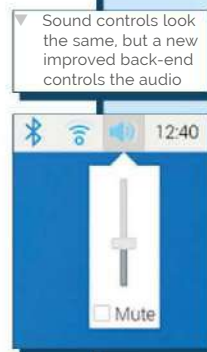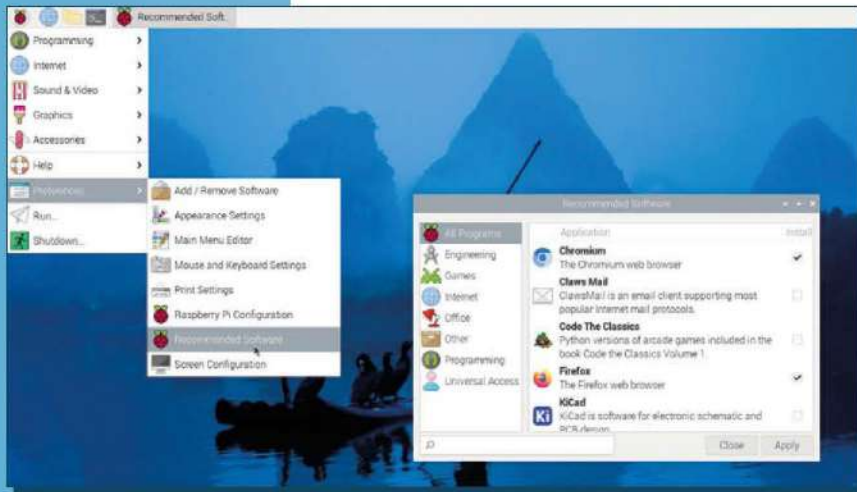
Installing software

Boosting your Raspberry Pi capabilities with new software is not always plain sailing

The 'standard' Raspberry Pi OS image contains a great range of software, from office applications to programming IDEs and multimedia tools, but that's just the tip of the iceberg. If you're looking for some software to do that special job for your new cool project, getting it on to your Raspberry Pi might be much easier than you think.

How do I install new software?

By far the easiest, pain-free way to enhance your Raspberry Pi is you use the official Recommended Software app. In here you will find carefully selected and tested software applications that have been approved by Raspberry Pi for use on Raspberry Pi. Find Recommended Software under the Preferences menu. However, this is by no means a definitive list of what's available.

▼ Get the best Raspberry Pi software easily with Recommended Software

The app I want is not available in Recommended Software

Through the command line, we can access APT, the Advanced Package Tool. This is our Swiss army knife of software installation and management. Often you will see installation instructions such as `apt install [packagename]` which invites you to do just that on the command line (Terminal). If you find you're getting errors, remember to add `sudo`, which gives APT the right permissions to install new software. You can also remove software or find new software using `apt [search string]`.

The app I want isn't on APT, but I have the source code

Here things get a bit more technical. Firstly, check whether the authors have created a separate APT repository and if they have provided instructions for adding it to APT's list of sources. That will be the most frictionless way. If not, check whether the app has dependencies – other software required for it to work, and make sure these are installed in advance. Finally, check your OS has the required tools installed to compile the app by running `sudo apt install build-essentials`. Now follow the compilation instructions very carefully.

Networking
Wi-Fi weird? Network nobbled? All about making connections.

This is possibly the most complicated topic. Modern networking is fiercely complicated and there are many ducks you have to get into a row for things to run smoothly. Although wired networking is straightforward these days, Wi-Fi is harder and things have changed significantly in Bookworm with the introduction of Network Manager, which makes network configuration easier than ever before but can cause problems with older scripts and utilities. Here, we'll look at getting a working network connection.

But it used to work…

A disadvantage of moving to the new Network Manager system is that a lot of pre-existing network configuration scripts and utilities will no longer work with a Raspberry Pi running Bookworm. If you find that a utility will no longer install, especially one that configures Wi-Fi, you will need to see if an update is available.

> ❝ First let's see if you have a connection at all ❞

No internet connection?

First let's see if you have a connection at all. The best thing to do is to start with a wired Ethernet connection and then move to a Wi-Fi connection (if desired) once everything is working. If it's not possible to move your Raspberry Pi to a wired connection, we can still poke around and see what's going on.

Make sure your Wi-Fi configured! The easiest way to do this is on the desktop itself. Click on the networking icon in the menu bar (next to the clock) and you can set the SSID (Network name) and password there. Check that you've set your country correctly. The operating system needs to know the country you are in to ensure only legal frequencies and channels are used, and will disable Wi-Fi until this has been done. You can check this in `raspi-config` under System Options.
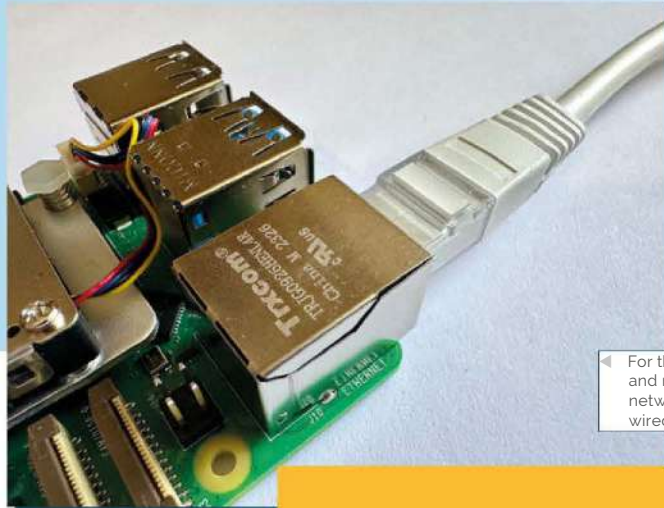
> For the easiest and most reliable networking, use a wired connection

Where's my Raspberry Pi?

A common problem when setting up a Raspberry Pi for remote (headless) access is trying to find it afterwards. Yes, it's probably sitting there in front of you, but where is it on the network? The first approach is to try the hostname. This is the network name of the computer, It defaults to `raspberrypi` but you can customise it at any time and may have set it in advance when using Raspberry Pi Imager. If you have access to a command line on another computer, try this command:
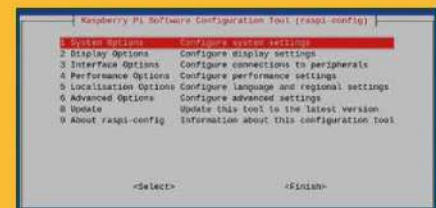
```
$ ping raspberrypi.local
```


If your machine is found then your network supports zeroconf networking and all is good. If you get 'Request timed out' or similar, it may not. If you've got access to the local console itself, you can run this command:

```
$ ip address show
```

Raspi-config
Your best friend for smooth configuration

Many of the troubleshooting tips here require you to run `raspi-config` or Raspberry Pi Configuration. Why? Well, rather than you having to learn all kinds of arcane GNU/Linux commands that can change from version to version, `raspi-config` wraps all the common configuration tasks up in a single menu-driven app. Get to know it!

Best practices
A few tips for looking after your Raspberry Pi setup

Keep things up to date

If you're using Raspberry Pi Desktop, you will be alerted when updates are available. Always make sure you install them as soon as possible as security updates are often included. If you're a command line user, make sure you run `sudo apt update && sudo apt full-upgrade` on a regular basis.

Protect your Raspberry Pi

The single best investment you can make for your Raspberry Pi is a good quality case. There is a huge selection available with alternatives for special applications such as industrial and even underwater! Check out *The MagPi* #131 (**magpi.cc/131**) for ten of our favourites.

Back it up!

Never have a single point of failure for your data. Follow the 3-2-1 rule: three copies of everything, two different media, one in a different location. You can image microSD cards directly or use services such as iDrive to automatically back up into the cloud. Cards fail!

Keep it cool

The new active cooling support in Raspberry Pi 5 means not only can you attach a fan to the board, but it'll only run when it needs to. Ideal for when peace and quiet are a concern. The official cooling kit combines a quiet fan with a sizable heatsink and many different cases with built in active cooling are already available.

You'll see three devices, lo, eth0 and wlan0, which are internal, Ethernet and Wi-Fi respectively. From here you can get your IP address. If local access is not a problem, a smartphone app like Fing can scan your network and recognise your Raspberry Pi. If that fails, you may not have a working network connection yet.

Unable to access using VNC

VNC has changed in Raspberry Pi OS Bookworm and, at the time of writing, many popular VNC clients are no longer compatible. The first thing to check is that you have enabled the VNC server in the first place as it is off by default. Open Raspberry Pi Configuration on the desktop or `raspi-config` on the command line and select Interface Options, then VNC, and select Yes to enable the server.

If you still can't get a connection, make sure your client is TigerVNC (note: not TightVNC). This has been tested and approved for use with Bookworm. If you still find you cannot connect, omit the ':0' that many VNC clients require after the hostname.

Unable to access using SSH

SSH is a way of securely getting to your command line remotely. Again, this is not enabled by default. You can enable it using Raspberry Pi Imager so you're ready to go, or use Raspberry Pi Configuration on the desktop or `raspi-config`. Just like with VNC, go to Interface Options and then SSH to enable.

DNS Problems

If you find you can ping your Raspberry Pi's IP address but not its hostname, there are a few things you can do. First check you've set the hostname correctly. The easiest way to do this is to open a Terminal window and run:

```
$ cat /etc/hostname
```

Not what you expected? You can safely change it in `raspi-config` by going to System Options then Hostname. Once changed, you'll need to reboot for changes to take effect.

If no joy, have you tried adding '.local' or '.broadband' after the hostname. Some routers require this.
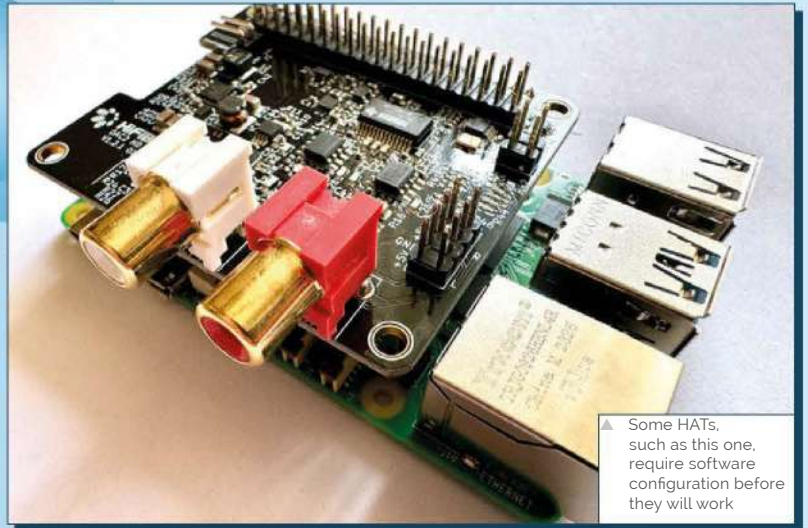
Finally, check the service that takes care of all this is running. From a command line run:

```
$ sudo systemctl status avahi-daemon
```

Check the status is 'active'. If it's not, try and restart it:

```
$ sudo systemctl start avahi-daemon
```

Now everything should be working as expected.

▲ Some HATs, such as this one, require software configuration before they will work

GPIO woe

LED not lighting? Sensor won't sense? All about common GPIO issues.

Connections to the GPIO come in different forms. There's good-fashioned 3v3 circuitry or more complex communications systems such as I2C and SPI. Not all of these are enabled by default to avoid conflicts. Finding out what is enabled and what is not is often key to getting things working.

> ❝ Start by building a simple circuit such as a classic LED project ❞

A simple test

To check everything is well with your GPIO, start by building a simple circuit such as a classic LED project like this: **magpi.cc/scratchled**. If you are bathed in a beautiful light, then you at least know the GPIO is functional.

My sensor is senseless

More complex components such as temperature sensors tend to use protocols rather than straightforward level changes. In these cases, Raspberry Pi OS needs to know what protocols are in use. Examples of these are 1Wire, I2C and SPI.

In all cases these need to be explicitly switched on using `raspi-config` or the desktop Raspberry Pi Configuration app in order to function properly. You'll find all these under Interfacing Options.

HAT a bit flat?

Just like stand-alone sensors, HATs often take advantage of protocols such as I2C and SPI. Often supplied install scripts will check this for you, but sometimes the HAT just flatly refuses to work. Just like with the sensors, check the requirements and enable what you need. Read the documentation.

Getting further help

One of the best things about Raspberry Pi is the community. It has a reputation for friendliness and acceptance of 'newbies'

- **Check out the Raspberry Pi forums at raspberrypi.com/forums for a wealth of expertise**

- **Look out for Raspberry Pi community groups on social media websites**

- **Check out literally years of questions and answers on Raspberry Pi Stack Exchange: magpi.cc/rpstackexchange**

Part 01

Get to know your
Raspberry Pi

Introducing your new credit-card-sized computer. Take a guided tour of the Raspberry Pi, find out how it works, and discover some of the amazing things you can do with it.

MAKER

Gareth Halfacree

Gareth is a freelance technology journalist, writer, and former system administrator in the education sector with a passion for open-source software and hardware.

magpi.cc/ halfacree

You'll Need

- Raspberry Pi Computer
- Raspberry Pi OS
- Raspberry Pi Camera Module (optional) **magpi.cc/camera**

Raspberry Pi is a remarkable device: a fully functional computer in a tiny, low-cost package.** Whether you're looking for a device you can use to browse the web or play games, are interested in learning how to write your own programs, or are looking to create your own circuits and physical devices, Raspberry Pi – and its amazing community – will support you every step of the way.

> **" Raspberry Pi – and its amazing community – will support you every step of the way "**

Raspberry Pi is known as a single-board computer, which means exactly what it sounds like: it's a computer, just like a desktop, laptop, or smartphone, but built on a single printed circuit board. Like most single-board computers, Raspberry Pi is small – it has roughly the same footprint as a credit card – but that doesn't mean it's not powerful: a Raspberry Pi can do anything a bigger and more power-hungry computer can do, from browsing the web and playing games to driving other devices.

The Raspberry Pi family was born from a desire to encourage more hands-on computer education around the world. Its creators, who joined together to form the non-profit Raspberry Pi Foundation, had little idea that it would prove so popular: the few thousand built to test the waters in 2012 sold out immediately, and more than 50 million have been shipped all over the world in the years since.

These boards have found their way into homes, classrooms, offices, data centres, factories, and even self-piloting boats and satellites.

Various models of Raspberry Pi have been released since the original Model B, each bringing either improved specifications or features specific to a particular use-case. Our Raspberry Pi Zero family, for example, are tiny versions of the full-size Raspberry Pi which drop a few features – in particular the multiple USB ports and wired network port – in favour of a significantly smaller layout and reduced power requirements.

All Raspberry Pi models have one thing in common: they're compatible, meaning that most software written for one model will run on any other model. It's even possible to take the very latest version of Raspberry Pi's operating system and run it on an original pre-launch Model B prototype. It will run more slowly, it's true, but it will still run.

In *The Official Beginner's Guide* (**magpi.cc/ beginnersguide**) you can learn about Raspberry Pi 4 Model B, Raspberry Pi 5, Raspberry Pi 400, and Raspberry Pi Zero 2 W: the latest and most powerful versions of Raspberry Pi. Everything you learn can be easily applied to other models in the Raspberry Pi family, so don't worry if you're using a different model or revision. Here is the first chapter from the book to give you a guided tour of Raspberry Pi.

A guided tour of Raspberry Pi

Unlike a traditional computer, which hides its inner workings in a case, a standard Raspberry Pi has all its components, ports and features out on display – although you can buy a case to provide extra protection, if you prefer. This makes it a great tool for learning about what the various parts

A. GPIO header
B. Wireless
C. RAM
D. RP1 I/O controller chip
E. Connector for fan
F. USB 2.0G
G. USB 3.0
H. Ethernet port
I. Power-over-Ethernet (PoE) pins
J. CSI/DSI camera/display port 0
K. CSI/DSI camera/display port 1
L. Micro HDMI 1
M. Connector for UART serial port
N. System-on-chip
O. Micro HDMI 0
P. Real-time clock battery header
Q. USB Type-C power in
R. Power button
S. Connector for PCI Express (PCIe)
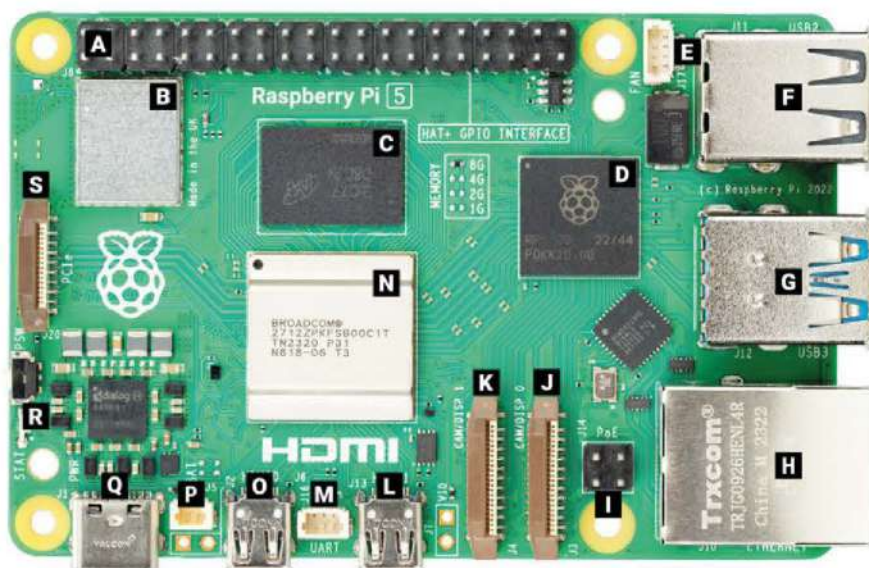
of a computer do, and also makes it easy to learn what goes where when it comes time to plug in the various other pieces of hardware – known as peripherals – you'll need to get started.

When you're using a Raspberry Pi with this book extract, try to keep it oriented the same way as in the pictures; otherwise it can get confusing when it comes to using things like the GPIO header (detailed in **Figure 1**).

While it may look like there's an overwhelming amount packed into such a tiny board, a Raspberry Pi is very simple to understand – starting with its components, the inner workings that make the device tick.

Raspberry Pi's components

Like any computer, Raspberry Pi is made up of many components, each of which has a role to play in making it work. The first, and arguably most important, of these can be found just to the left of the centre point of the board (see **Figure 2**), covered in a metal cap: this is the system-on-chip (SoC).

The name 'system-on-chip' is a great indicator of what you would find if you prised the metal cover off: a silicon chip, known as an integrated circuit, that contains the bulk of Raspberry Pi's system. This integrated circuit includes a central processing unit (CPU), commonly thought of as the 'brain' of a computer, and a graphics processing unit (GPU), which handles the visual rendering and display output side of things.

> **"** While it may look like there's an overwhelming amount packed into such a tiny board, a Raspberry Pi is very simple to understand **"**

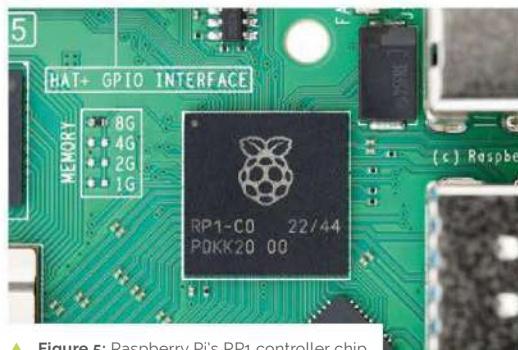▼ **Figure 2:** Raspberry Pi's system-on-chip (SoC)
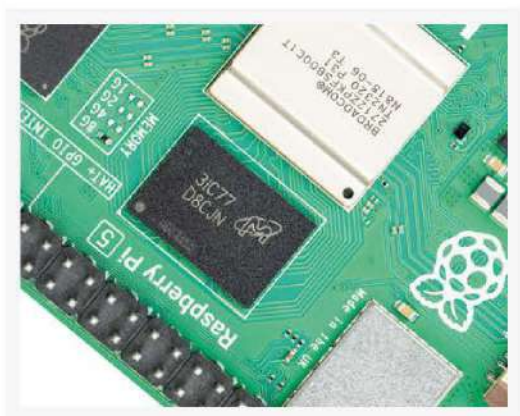
▲ **Figure 3:** Raspberry Pi 5's random access memory (RAM)

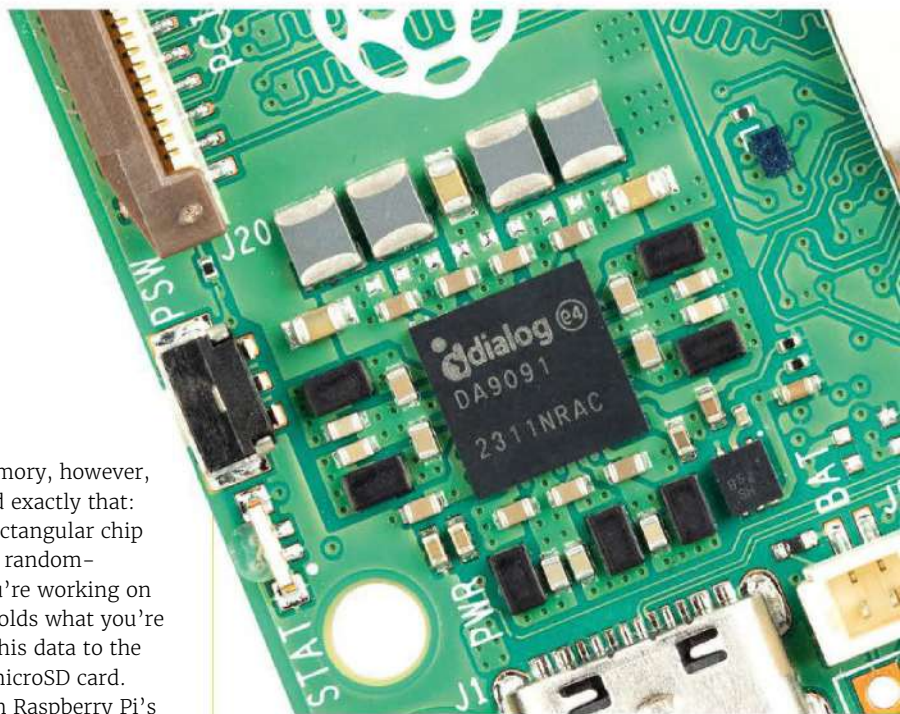▶ **Figure 6:** Raspberry Pi's power management integrated circuit (PMIC)

A brain is no good without memory, however, and just above the SoC you'll find exactly that: a small, black, plastic-covered rectangular chip (**Figure 3**). This is Raspberry Pi's random-access memory (RAM). When you're working on Raspberry Pi, it's the RAM that holds what you're doing. Saving your work moves this data to the more permanent storage of the microSD card. Together, these components form Raspberry Pi's volatile and non-volatile memory: the volatile RAM loses its contents whenever Raspberry Pi loses power, while the non-volatile memory in the microSD card keeps its contents.

At the top left of the board you'll find another metal lid covering the radio, the component that Raspberry Pi the ability to communicate wirelessly with devices (**Figure 4**). In fact, the radio itself fills the role of two other common components: a Wi-Fi radio that connects to computer networks; and a Bluetooth radio that connects to peripherals like mice and sends or receives data from nearby smart devices like sensors or smartphones.

Another black, plastic-covered chip marked with the Raspberry Pi logo can be found on the right side of the board, near the USB ports (**Figure 5**). This is RP1, a custom I/O controller chip which communicates with the four USB ports, the Ethernet port, and most low-speed interfaces to other hardware.

Another black chip, smaller than the rest, can be found a little bit above the USB C power connector at the bottom left of the board (**Figure 6**). This is known as a power management integrated circuit (PMIC); it takes the power that comes in from the USB C port and turns it into the power your Raspberry Pi needs to run.

The final black chip, below RP1 and positioned at a jaunty angle, helps the RP1 in handling Raspberry Pi's Ethernet port. It provides what is known as an Ethernet PHY, providing the physical interface which sits between the Ethernet port itself and the Ethernet controller in the RP1 chip.

Don't worry if this seems like a lot to take in: you don't need to know what each component is or where to find it on the board in order to use Raspberry Pi.

▼ **Figure 4:** Raspberry Pi's radio module

▲ **Figure 5:** Raspberry Pi's RP1 controller chip
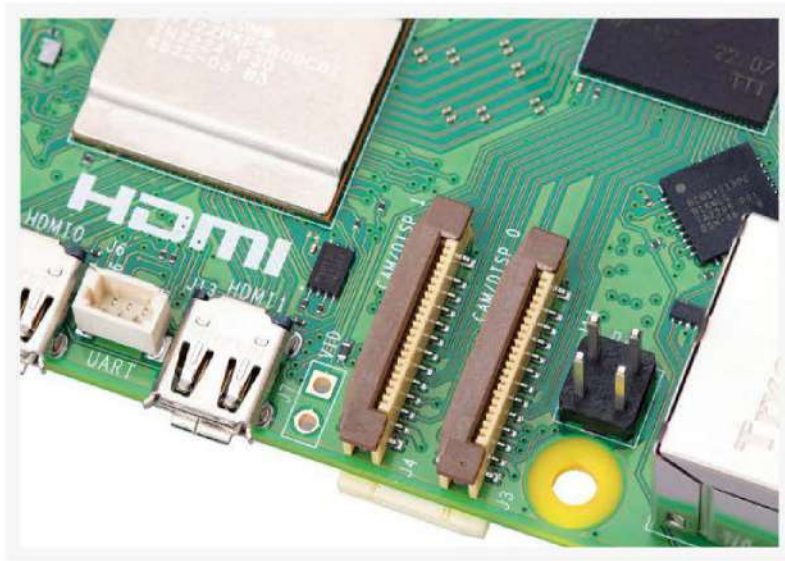
Raspberry Pi's ports

Raspberry Pi has a range of ports, starting with four Universal Serial Bus (USB) ports (**Figure 7**) at the middle and top of its right-hand edge. These ports let you connect any USB-compatible peripheral – like keyboards, mice, digital cameras, and flash drives – to your Raspberry Pi. Speaking technically, there are two types of USB ports on Raspberry Pi, each relating to a different Universal Serial Bus standard: the ones with black plastic inside are USB 2.0 ports and the ones with blue plastic are newer and faster USB 3.0 ports.

Next to the USB ports is an Ethernet port, also known as a network port (**Figure 8**). You can use this port to connect your Raspberry Pi to a wired computer network with a cable that uses what is known as an RJ45 connector. If you look closely at the Ethernet port, you'll see two light-emitting diodes (LEDs) at the bottom. These are status lights which, when lit or blinking, let you know the connection is working.

Just to the left of the Ethernet port, on the bottom edge of Raspberry Pi, is a Power-over-Ethernet (PoE) connector (**Figure 9**). This connector, when paired with the Raspberry Pi 5 PoE+ HAT – Hardware Attached on Top, a special add-on board designed for Raspberry Pi – and a suitable PoE-capable network switch, lets you power Raspberry Pi from its Ethernet port without having to connect anything to the USB Type-C connector. The same connector is also available on Raspberry Pi 4, though in a different location; Raspberry Pi 4 and Raspberry Pi 5 use different HATs for PoE support.
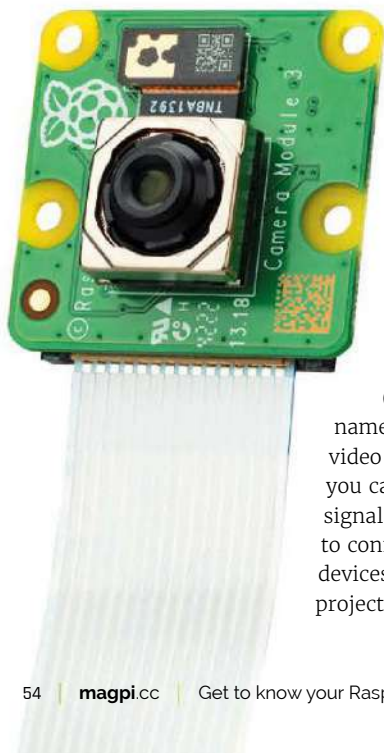

▲ **Figure 9:** Raspberry Pi's Power-over-Ethernet connector

▲ **Figure 10:** Raspberry Pi's camera and display connectors

▼ **Figure 11:** Raspberry Pi's camera module

▼ **Figure 12:** Raspberry Pi's micro HDMI ports

Directly to the left of the PoE connector are a pair of strange-looking connectors with plastic flaps you can pull up; these are the camera and display connectors, also known as the Camera Serial Interface (CSI) and Display Serial Interface(DSI) ports (**Figure 10**).

You can use these connectors to connect a DSI-compatible display like the Raspberry Pi Touchscreen Display or the specially designed Raspberry Pi Camera Module family (**Figure 11**). You'll learn more about camera modules and display ports in this month's MIPI tutorial (see page 70). Either port can act as a camera input or display output so you can have two CSI cameras, two DSI displays, or one CSI camera and one DSI display running on a single Raspberry Pi 5.

To the left of the camera and display connectors, still on the bottom edge of the board, are the micro High Definition Multimedia Interface (micro HDMI) ports, which are smaller versions of the connectors you can find on a games console, set-top box, or TV (**Figure 12**). The 'multimedia' part of its name means that it carries both audio and video signals, while 'high-definition' means you can expect excellent quality from both signals. You'll use these micro HDMI ports to connect Raspberry Pi to one or two display devices, such as a computer monitor, TV, or projector.

Between the two micro HDMI ports is a small connector labelled 'UART,' which provides access to a Universal Asynchronous Receiver-Transmitter (UART) serial port. You won't use that port in this book extract, but you may need it in the future for communicating with, or troubleshooting, more complex projects.

To the left of the micro HDMI ports is another small connector labelled 'BAT', where you can connect a small battery to keep Raspberry Pi's real-time clock (RTC) ticking, even when it's disconnected from its power supply. You don't need to connect a battery to use Raspberry Pi, though, since it will automatically update its clock when turned on, so long as it has access to the internet.

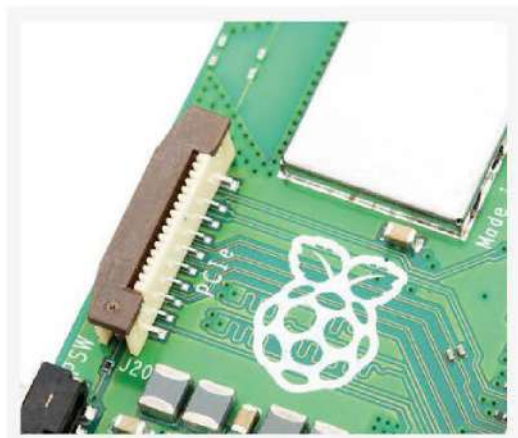▲ **Figure 13:** Raspberry Pi's USB Type-C power port
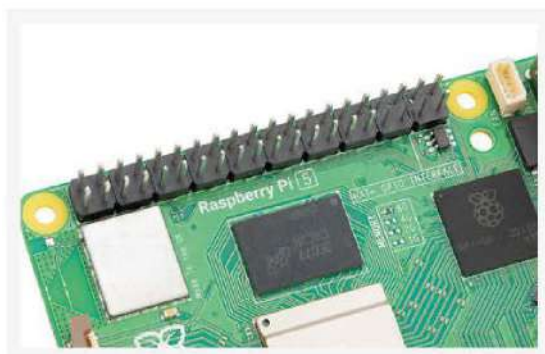
▲ **Figure 15:** Raspberry Pi's GPIO header

At the bottom left of the board is a USB C power port (**Figure 13**), used to provide Raspberry Pi with power through a compatible USB C power supply. The USB C port is a common sight on smartphones, tablets, and other portable devices. While you could use a standard mobile charger to power your Raspberry Pi, for best results you should use the official Raspberry Pi USB-C Power Supply: it's better at coping with the sudden changes in power requirements that can occur when your Raspberry Pi is working particularly hard.

" At the top edge of the board are 40 metal pins "

At the left edge of the board is a small button facing outwards. This is Raspberry Pi 5's new power button, used to safely shut down your Raspberry Pi when you're finished with it. This button is not available on Raspberry Pi 4, or older boards.

Above the power button is another connector (**Figure 14**), which, at first glance, looks like a smaller version of the CSI and DSI connectors. This almost-familiar connector connects to Raspberry

Pi's PCI Express (PCIe) bus: a high-speed interface for add-on hardware like Solid State Disks (SSDs). To use the PCIe bus, you'll need the Raspberry Pi PCIe HAT add-on to convert this compact connector to a more common M.2-standard PCIe slot. You don't need the HAT to make full use of Raspberry Pi, though, so feel free to ignore this connector until you need it.

At the top edge of the board are 40 metal pins, split into two rows of 20 pins (**Figure 15**). These pins make up the GPIO (general-purpose input/output) header, an important feature of Raspberry Pi, that lets it talk to additional hardware from LEDs and buttons all the way to temperature sensors, joysticks, and pulse-rate monitors.

There's one final port on Raspberry Pi, but you won't see it until you turn the board over. Here on the underside of the board you'll find a microSD card connector positioned almost exactly underneath the top-side's connector marked 'PCIe' (**Figure 16**). This connector is for Raspberry Pi's storage device: the microSD card inserted in here contains all the files you save, all the software you install, and the operating system that makes your Raspberry Pi run. It's also possible to run your Raspberry Pi without a microSD card by loading its software over the network, from a USB drive, or from an M.2 SSD.

▼ **Figure 16:** Raspberry Pi's microSD card connector

▲ **Figure 14:** Raspberry Pi's connector for PCI Express.

► **Figure 18:** The ports are found at the rear of Raspberry Pi 400

Raspberry Pi 400

Raspberry Pi 400 takes the same components as Raspberry Pi 4, including the system-on-chip and memory, but places them inside a convenient keyboard housing. As well as protecting the electronics, the keyboard housing takes up less room on your desk and helps keep your cables tidy.

While you can't easily see the internal components, you can see the external bits and pieces, starting with the keyboard itself (**Figure 17**). In the upper right corner are three light-emitting diodes (LEDs): the first lights up when you press the Num Lock key, which switches some of the keys to act like the ten-key number pad on a full-size keyboard; the second lights up when you press Caps Lock, which makes the letter keys upper-case rather than lower-case; and the last lights up when Raspberry Pi 400 is powered on.

At the back of Raspberry Pi 400 (**Figure 18**) are the ports. The left-most port is the general-purpose input/output (GPIO) header. This is the same header shown in **Figure 15**, but flipped: the first pin, Pin 1, is at the top-right, while the last pin, Pin 40, is at the bottom-left.

Next to the GPIO header is the microSD card slot. Like the slot on the underside of Raspberry Pi 5, this holds the microSD card that serves as storage for Raspberry Pi 400's operating system, applications, and other data. A microSD card comes pre-installed in Raspberry Pi 400. To remove it push gently on the card until it clicks and springs out, then pull the card the rest of the way out. When you put the card back in, make sure the shiny metal contacts are facing downwards. Push the card in gently until it clicks, which means it's locked into place.

The next two ports are the micro HDMI ports, used to connect a monitor, TV, or other display. Like Raspberry Pi 4 and Raspberry Pi 5, Raspberry Pi 400 supports up to two HDMI displays. Next to these is the USB C power port, used to connect an official Raspberry Pi Power Supply, or any other compatible USB C power supply. The two blue ports are USB 3.0 ports, which provide a high-speed connection to devices like solid-state drives (SSDs), memory sticks, printers, and more. The white port to the right of these is a lower-speed USB 2.0 port, which you can use for the Raspberry Pi Mouse included with the Raspberry Pi 400.

The final port is a gigabit Ethernet network port, used to connect Raspberry Pi 400 to your network using an RJ45 cable as an alternative to using the device's built-in Wi-Fi radio.

► **Figure 17:** Raspberry Pi 400 has an integrated keyboard

Raspberry Pi Zero 2 W

Raspberry Pi Zero 2 W (**Figure 19**) is designed to offer many of the same features as the other models in the Raspberry Pi family, but in a much more compact design. It's cheaper and draws less power, but it also lacks a few ports found on the larger models.

Unlike Raspberry Pi 5 and Raspberry Pi 400, Raspberry Pi Zero 2 W lacks a wired Ethernet port. You can still connect it to a network, but only using a Wi-Fi connection.

You should also notice a difference in the system-on-chip: it's black instead of silver and there's no separate RAM chip visible. This is because the two parts – SoC and RAM – are combined into one chip, marked with an etched Raspberry Pi logo, and placed roughly in the middle of the board.

> ❝ Raspberry Pi Zero 2 W is designed to offer many of the same features as the other models ❞

The far left of the board has the usual microSD card slot for storage, and below that is a single mini HDMI port for video and audio. Unlike Raspberry Pi 5 and Raspberry Pi 400, Raspberry Pi Zero 2 W only supports a single display.

To the right are two micro-USB ports: the left-hand port, marked 'USB', is a USB On-The-Go (OTG) port which is compatible with OTG adapters to connect keyboards, mice, USB hubs, or other peripherals; the right-hand port, marked 'PWR IN', is the power connector. You can't use a power supply designed for Raspberry Pi 4 or Raspberry Pi 400 with Raspberry Pi Zero 2 W, since they use different connectors.

At the very right of the board is a Camera Serial Interface you can use to connect a Raspberry Pi Camera Module.

Finally, Raspberry Pi Zero 2 W has the same 40-pin general-purpose input/output (GPIO) header as its bigger siblings, but it's supplied unpopulated. This means it doesn't have any pins fitted. If you want to use the GPIO header you'll need to solder a 2×20 2.54mm pin header in place — or purchase the Raspberry Pi Zero 2 WH, which has a header already soldered into place. ▯
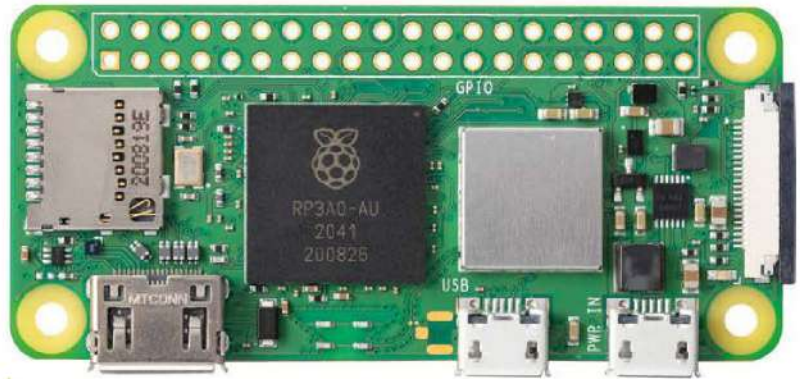
The Official Raspberry Pi Beginner's Guide

This extract is taken from The Official Raspberry Pi Beginner's Guide 5th Edition. This 290-page book is packed with guidance on how to set up your Raspberry Pi, install its operating system, and start using this fully functional computer.

With this book, you can start coding projects, with step-by-step guides using the Scratch 3, Python, and MicroPython programming languages.

Plus you'll experiment with connecting electronic components, and have fun creating amazing projects. You can buy a copy from our online store, or read it in the Bookshelf app in Raspberry Pi OS.
magpi.cc/beginnersguide
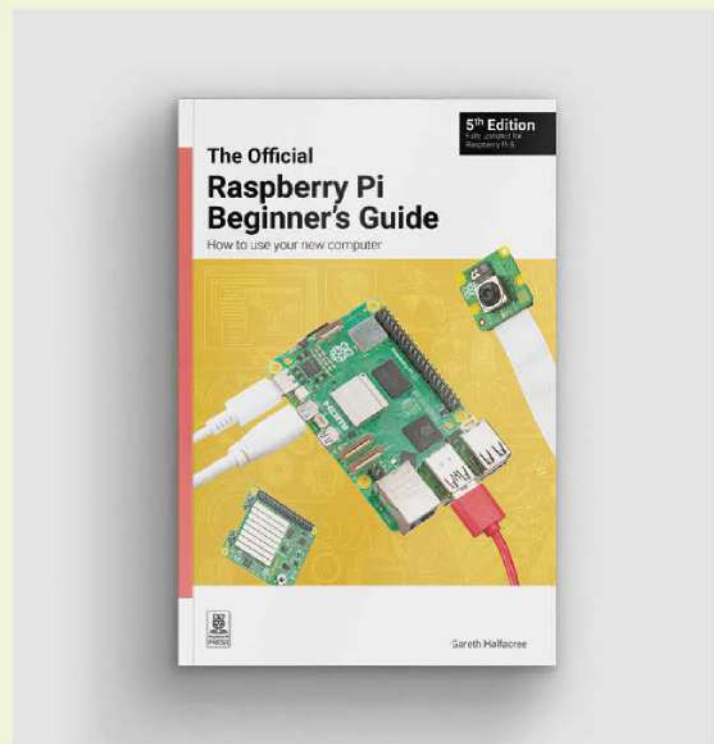
Twin-lens reflex:
Old-school cool

Get started with vintage Yashica cameras

Dr Andrew Lewis

Dr Andrew Lewis is a specialist fabricator and maker, and is the owner of the Andrew Lewis Workshop.

Vintage cameras are a bit like vintage cars. The older they are, the fewer things there are to go wrong. When they do go wrong, the easier they are to fix. In this article, you'll take a look at a classic twin-lens reflex (TLR) camera, see the common problems they acquire over time, and hopefully see why it's worth the effort of getting them back into good working order. You'll also see how modern technology, like Raspberry Pi Pico, can be used to help with the repair process, and learn a few old-school tips that will help you take good photographs.

GRAIN NOT PIXELS

The TLR style of camera is a design classic. It's simple, easy to maintain and, in the case of cameras like the Yashica TLR, practically modular. Accepting a 120 (or 127) film to take a total of twelve 6 cm square exposures, the Yashica TLR is capable of taking absolutely stunning photographs.

At their simplest level, film cameras all have the same very basic design. A lens of some type focuses light through a shuttered aperture for a certain amount of time, projecting an image onto a sheet of light-sensitive chemicals. Everything else about a camera is a design feature – lenses or pinholes, winding mechanisms, mechanical shutters, timers, film size, and viewfinder types are all essentially design choices made by the manufacturer or the end user. In most cameras, these things get wound together into a package and sold to the end user as a complete item that can't really be changed. A few very expensive (think 'did I just pay more for a
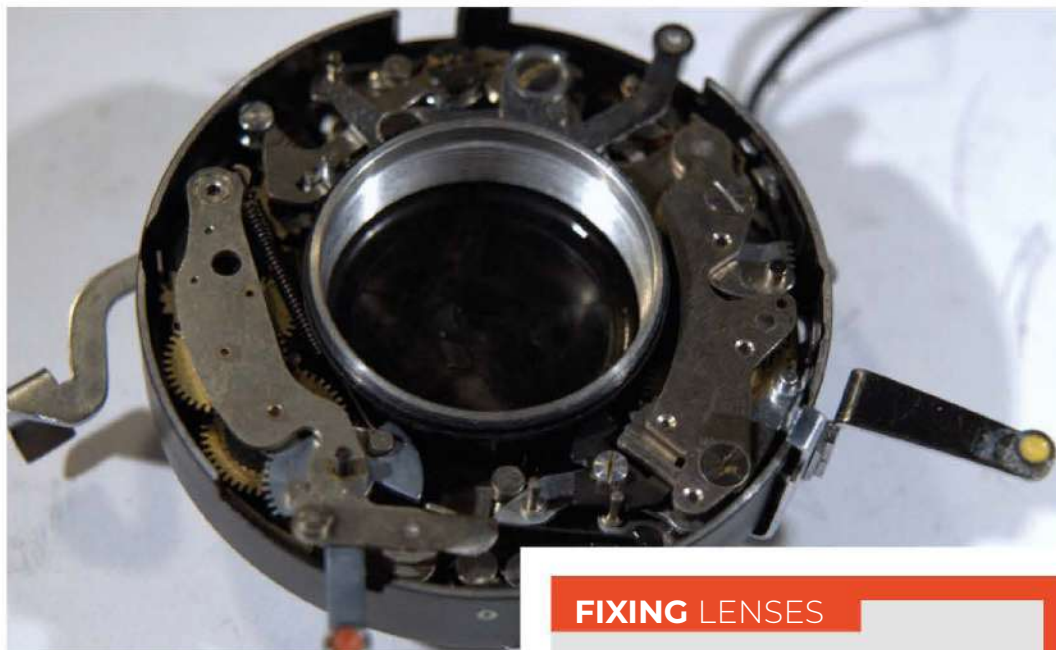
camera than a car?' type of expensive) cameras have an impressive range of interchangeable parts, but it's rare for a moderately priced camera to be modular or even moderately hackable to the extent that the Yashica TLR is.

If you're lucky, you can find a Yashica TLR for sale at around £60, although it's likely that it'll be faulty and will need some work to get going. With the flexibility of the Yashica TLR, it's probably going to be much easier to fix than you might think. The main

> **If you're lucky, you can find a Yashica TLR for sale at** around £60, although it's likely that it'll be faulty

areas you'll be looking at when you're assessing a TLR camera are the lenses and focusing systems, the film winder, and the shutter. The cosmetics of the camera don't really affect its function, but the condition of the light seals does need to be checked and they should be replaced if they're worn out.

The camera's lenses screw into the lens assembly and into the shutter. One problem to watch out for is that the top viewfinder lens and the bottom shutter lens both need to be screwed into place by →

FIXING LENSES

The lenses of the Yashica TLR camera are glued together using a blend of tree sap and turpentine called Canada balsam. Over time, variations in temperature and pressure can cause these lenses to separate and leave flecks or mist between the lens elements that will affect the quality of the photographs you take. Fixing this problem isn't as difficult as you might imagine, and there are a few different ways you can do it depending on the tools you have access to and your confidence level.

CLEAN. LUBE. ADJUST

One method is to use heat to remelt the balsam and then apply pressure to the lens while it cools. This can be done by hand with gloves, a heat-resistant foam pad, and a wooden stick with a felt end. Separate the lens from the camera, and heat it using a temperature-controlled heat gun until you see the balsam melt, then just push the two lenses together. Get comfortable before you start because this is a slow process, and you need to heat the elements gradually and evenly, then apply steady pressure for several minutes while the elements cool slowly. Allowing the elements to cool too quickly can cause them to shatter. If this process doesn't work for you, you can instead remove the existing balsam using a solvent like Xylene, and glue the lenses back together using a modern lens glue. If the lenses are not fully separated but are clouded or spotted internally, applying some heat will help get them apart. How the balsam reacts to the heat seems to be partly down to the method of balsam application originally used, so mileage may vary with different lenses and you'll need to experiment to find the best method for your particular lens. A quick internet search on the subject will provide some additional methods and specific glues to consider.

Right
The parts of a Yashica camera are pretty much discrete, but there are points where different parts interlock with each other, like the shutter and the winder mechanism, or the dials on the face of the camera. Keep an eye out for these interlocks, and make sure you put them back in the right place when you're reassembling things. As always, plenty of photographs will help you

OPEN AND SHUT

There are a few things that can go wrong with the Yashica TLR camera shutter. General poor maintenance can lead to the shutter getting stuck or running at the wrong speed, and that's easy enough to fix with a little bit of solvent and some TLC. The question is, how do you check that your camera is firing accurately? A quick and easy way is to make a simple light detector with a Raspberry Pi Pico, and use it to check how long the shutter lets light into the camera.

BEWARE OF THE SELF DESTRUCT

There's an innocuous-looking lever on Yashica TLR cameras, with an X and an M mode. This lever can break your camera so badly that you'll need to disassemble the shutter mechanism to get it working again. The lever adjusts the shutter to synchronise with the firing of the flash. Normally, this lever is set to X, which is the correct setting for a standard, instantaneous modern electronic flash. The M mode adjusts the shutter firing time to allow some extra time for old-style flash bulbs to reach their peak. When the camera is in M mode, the self-timer can not be used. In a normally working, well-maintained camera, it shouldn't be possible to set the self-timer when the camera is in M mode. However, most old cameras are not in peak condition and the mechanism that is supposed to stop that happening doesn't work properly. If you fire that self-timer while the camera is in M mode, you're going to be doing the camera equivalent of gear-shifting a car from forward to reverse, at speed, without using the clutch. In short, you'll need to completely disassemble the shutter and crank mechanism, reset all of the parts, and then go and have a bit of a lie-down. Most people lock the lever into position using a small screw or a well-positioned elastic band.

the correct amount or the viewfinder image won't be a true representation of the image in focus. If the camera you're fixing has been knocked around a lot, it's possible for a lens to shift and knock the camera out of focus. The easiest way to set this is to remove the back and front cover of the camera and set up a film spool with a piece of greaseproof paper the same width as a piece of 120 film wound onto it. Lock the camera in place using a tripod or
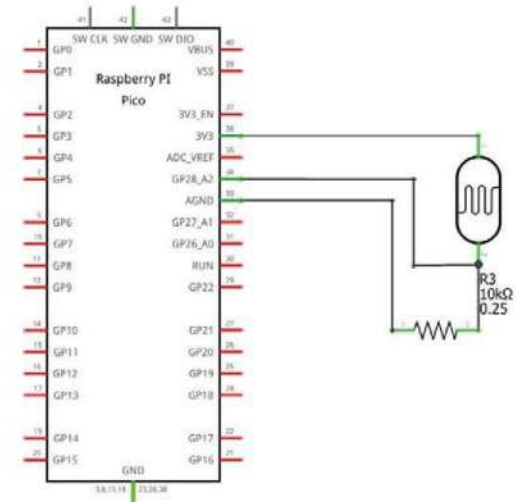
Above
Connect an LDR and $10\,\text{k}\Omega$ resistor, as shown in the diagram, and then place the LDR inside the camera behind the shutter. Close the back of the camera as well as you can to prevent light leaking in from the back, and use a simple MicroPython program to time how long the shutter stays open when the button is pressed. If the shutter is running slow, then you probably need to clean and lubricate the shutter mechanism

QUICK TIP

The rotational orientation of lens pieces relative to each other is important. Don't take them apart without marking their alignment first.

Left
The Yashica MAT LM has a built-in light meter, although it isn't actually very good. If you aren't bothered about maintaining a pristine factory-standard camera, you can remove the light meter by removing a few screws

Left

some well-placed heavy objects, turn the focus knob to its lowest point, and place a distinctive object exactly one metre away from the camera lens. With no macro lenses fitted, the camera should have a minimum focus of one metre. With the greaseproof 'film' loaded into the camera, set the shutter to bulb mode and hold it open so that you can see the scene in front of the camera projected onto the greaseproof paper. Look at the projected image and check whether it's in focus. If it isn't, you can adjust the focus by screwing the bottom lens in or out. Now look at the viewfinder screen, and check that the viewfinder image is also in focus. If it isn't, screw or unscrew the top lens of the camera until the image resolves. Hold the threads in place with a dab of lacquer or glue. Your camera should now be focused well enough for general use.

> **If you really want the camera to stand out,** you can replace the leather with something different

When it comes to cosmetics, it's amazing how much a bit of black Sharpie, a chrome touch-up pen, and some wax polish can accomplish. A couple of hours of cleaning and applying subdued paint effects can make the camera look almost new, and if you really want the camera to stand out, you can replace the leather with something different.

Upcycle a Sonos Play:1

If you've got a broken or unused Sonos speaker sulking in the corner, it's possible to upcycle it for many different purposes using Raspberry Pi

MAKER

PJ Evans

PJ is a writer, software engineer and tinkerer. His Play:1 now plays endless Rick Astley.

mastodon.social/ @mrpjevans

Danger! High voltage.

Many Sonos products have direct mains input which means residual charge can be present on the circuit board.

magpi.cc/dischargecap

Upcycling and the right to repair are hot topics right now. Just because an electronic device has failed, or is no longer required, it shouldn't mean instant landfill. When we came across a sad Sonos Play:1 that was more of a 'Silence:1', we decided to investigate the possibility of repurposing the high-quality speaker and enclosure. The result was a new lease of life with plenty of options within its capabilities. This tutorial shows how to do it and is not just for a Play:1, but more of an example of how you can give dead tech a new purpose.

01 Build your stack

Let's start with Raspberry Pi itself. We selected a 3A for this project thanks to its smaller form factor which means it doesn't get in the way of the main speaker in the unit. You could also use a Raspberry Pi Zero 2. There are many choices for audio output, but the one thing you need is amplification. Most DAC HATs are line-out only, relying on external amplification, so make sure yours can be wired directly to speakers. The Sonos Play:1 speaker is 4 Ohm so we selected a matching amp: in this case, the Justboom DAC & AMP combo. Assemble everything according to instructions, and from now on use the 20V power supply connected to the HAT to power everything.

02 Prepare the operating system

As is traditional in these tutorials, it's operating system time. Depending on your plans, it's your choice whether you have a desktop or not (VNC into a speaker? Why not?) but we

went for Raspberry Pi OS Lite (64 bit) and wrote the image to an SD card using Raspberry Pi Imager, making sure Wi-Fi and SSH access were configured in advance as, once in the enclosure, we won't have keyboard or video access. Once installed, make sure you can get SSH access over your network then run `sudo apt update -y & sudo apt upgrade -y` so that everything is up to date.

▲ The original Sonos Play:1. A powerful speaker assembly in a small good-looking unit. Lucky for us there's a lot of space inside!

03 Disassemble your Sonos Play:1

Let's create some space for the Raspberry Pi and the amp. Carefully remove the rubber strip on the base that hides the screws. Now remove the Torx screws. Lift out the base then slide the speaker
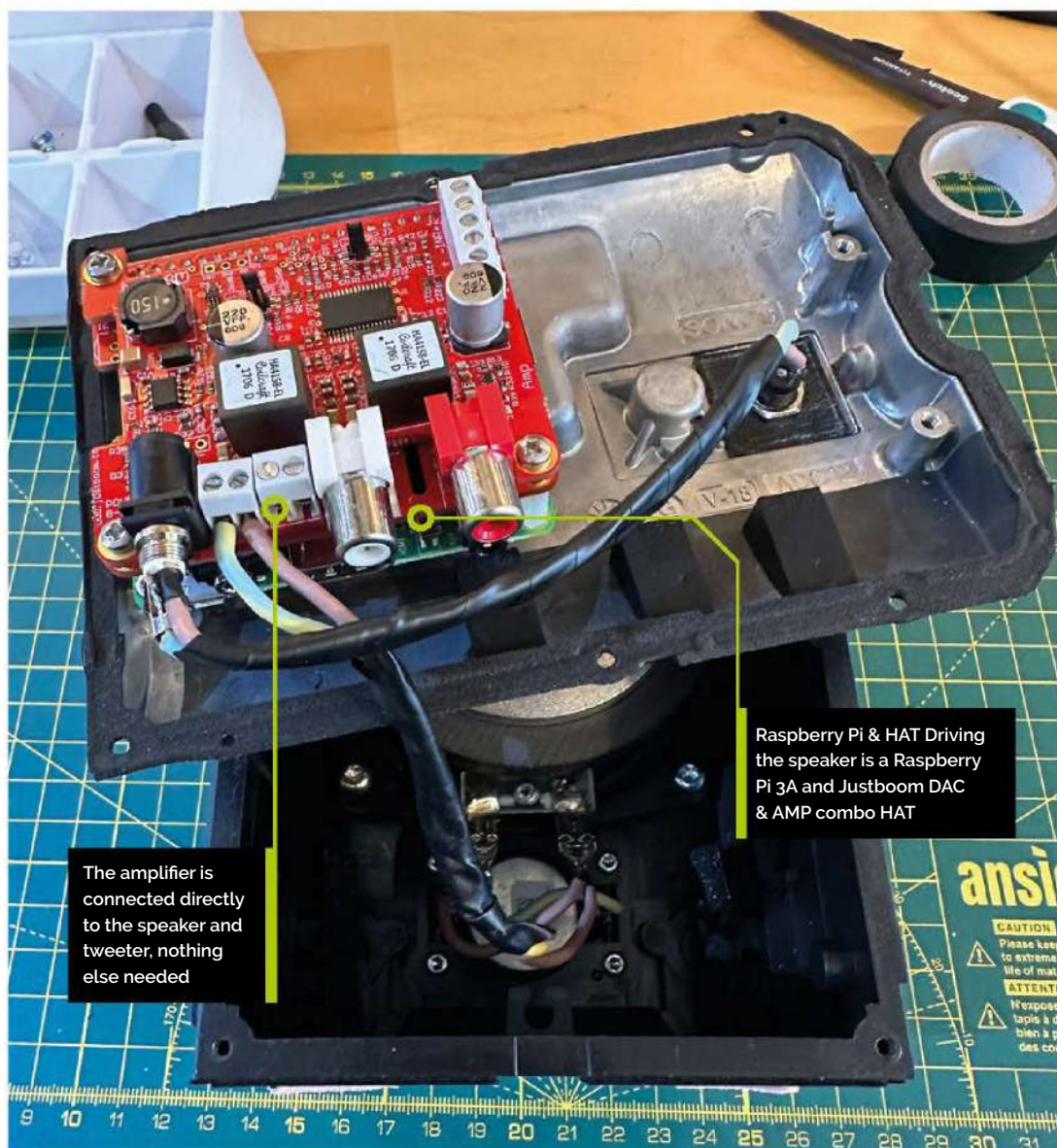
The amplifier is connected directly to the speaker and tweeter, nothing else needed

Raspberry Pi & HAT Driving the speaker is a Raspberry Pi 3A and Justboom DAC & AMP combo HAT

You'll Need

- Sonos Play:1 (or similar)
- Amp HAT (**magpi.cc/amp4**)
- 20V (at least 12V) power supply with barrel connector (**magpi.cc/20v4a**)
- Approx 1m speaker-grade wiring
- 20V wiring (optional)
- Size 5 and 6 Torx screwdrivers
- Rotary tool and 3mm bit

grille off. Remove the tape from each corner to reveal the screws holding the top section and remove them. Pop off the top section and detach the ribbon cable from the mainboard. Now remove the remaining screws to carefully separate the front section from the back. For a complete guide, see this iFixIt article (**magpi.cc/play1mb**).

04 Remove the mainboard

IMPORTANT: This part involves potentially harmful electricity. Minors must be supervised. Take a look at the mainboard on the rear part of the enclosure. See the three brown capacitors? They are likely to be holding charge from the mains electricity. Do not touch them,

especially the contacts to the motherboard. Carefully remove the wiring loom to the speakers then unscrew the board. Remove the board by the edges. Ideally, at this point you should discharge the capacitors for safety. See the guide in the warning box. Either way, discard the mainboard at this point unless you intend to recycle it.

05 Clear out the wiring

At this point you should have a plain metal backplate to the whole enclosure. This is where the Raspberry Pi and amplifier will be installed. Turning our attention to the main section, you'll see some wiring still installed. We need to remove all of this. Start by looking at the

Top Tip 👍

Ice cube trays are your friend

There are a lot of bits you need to keep track of during disassembly. Consider using an ice cube tray to keep things separate and in order of use.

▶ The Justboom DAC & AMP is a DAC HAT with an amplifier that 'piggybacks' on top to create a single device

▶ Here you can see the original PCB for the Sonos system. The large brown capacitors may be carrying high voltage charges and should not be touched
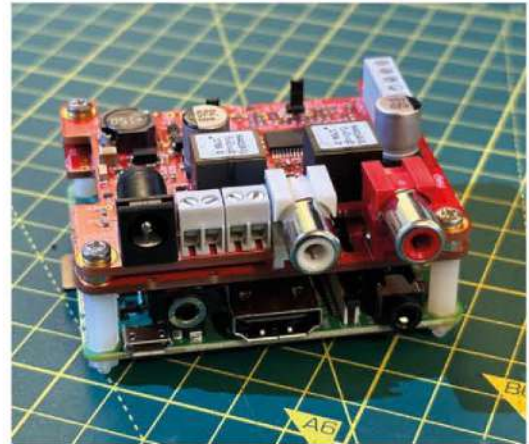
speaker terminals. The wiring loom is connected using spades, and we can reuse those, so using needle-nose pliers, remove the terminals. Make sure you note which are positive and negative; they are different sizes and we want to make sure we reattach using the same polarity. Finally, clip out the smaller wires near the base which are no longer required.

06 Build the new wiring

Time to heat up the soldering iron. Clip off the spades from the original wiring (which can now be discarded). Make sure the speaker wire you have chosen is a suitable size to fit in the screw terminals of the amplifier. Now, matching the original polarity, take a decent length of speaker wire (you can trim it later) and solder to the main speaker spades, then using a 10cm additional strip, solder the tweeter spades to the main spades so they are in parallel. Silver the opposite end of the wire and screw into the + and – terminals of the amplifier for the left channel. Once connected, return the spades to their original terminals.

07 Configure the DAC

Let's return to the Raspberry Pi. With the speakers connected, boot up and get a command line prompt either directly or via SSH. At this point the DAC & amp are unknown to the operating system, so we need to make some changes. Instructions vary for different DACs. For Justboom, we need to edit config.txt to load the drivers at boot time. Run this command:

```
sudo nano /boot/config.txt
```

Find the line `dtparam=audio=on` and comment it out and add the lines below so it matches:

```
#dtparam=audio=on
dtparam=audio=off
dtoverlay=justboom-digi
```

CTRL+X to save, then **Y** to exit. Reboot now with `sudo reboot`.

08 Test time!

Let's make some noise! White noise to be exact. Get back to a command prompt and first let's check the volume levels. Enter `alsamixer` and you'll see some controls. Use the **arrow keys** to move along to "Digital" and turn it up to about 50%. If you see "MM" there press **M** to unmute the channel. Press **ESC** to leave. Now run this command:

```
speaker-test -c 1
```

If all is well, you'll hear a static-like sound from the speakers. Lightly press your fingertip against each speaker to feel the vibration. When you're happy both are working, use **CTRL+C** to stop playback.

▼ The back of the unit with the Raspberry Pi stack installed. All that's left is to wire it to the speakers

that can hold a chassis-mount barrel socket (files here: **magpi.cc/play1socket**). Then you can create a link between the socket and another connector internally. Now the power supply is no longer tethered to the Sonos Play:1.

11 Reassemble

Before getting the screwdriver back out, make sure everything is still working as expected and there's no chance of any short circuits when the unit is put back together. If you have too much slack on the speaker lead, now is the time to trim it down and re-silver. You should have enough that you can easily open up the two halves of the enclosure should you need to. Now reverse the earlier process. Reattach the backplate to the main body, add on the top piece, slide on the speaker grille and then the base and its rubber strip.

09 Mounting the Raspberry Pi

Examining the Sonos Play:1 backplate we encounter a bit of luck. The top two screw terminals are exactly the same width apart as the standard Raspberry Pi mounting holes. Hurrah! It's not all plain sailing though. They are M.3 size and the Raspberry Pi holes are M2.5. So if you're feeling brave, use a low-speed rotary tool with a 3mm bit to carefully bore out the two holes to M.3 size. Note: You can permanently damage your Raspberry Pi at this point, take your time. Now, using the screws from the original board, you can mount the stack to the backplate. It's a good idea to line the surface with insulation tape to avoid short circuits.

12 Final test

Once everything is back together it's time for a final test run. Power up the upcycled unit, make sure you can get a Wi-Fi connection (despite the thick casing, we've found the Wi-Fi to remain reliable – of course there's nothing to stop you using a wired connection if you prefer). Run the speaker test again, altering the volume if you need to. You may have noticed a potential problem. We've only got one speaker connected to the left channel? Don't we have stereo in 2024? Well, yes and we need to mix the two channels and also find a cool application for our new audio toy. That's for next month. M

10 Power wiring

We've been using the 20V power supply as the standard Raspberry Pi 5V supply isn't enough to drive the amplifier as well. Now the original mainboard has been removed, there is a space previously occupied by the Ethernet connector that can be used to feed the power through to the board. If you're feeling fancy and have the kit, consider 3D printing a cover for the aperture
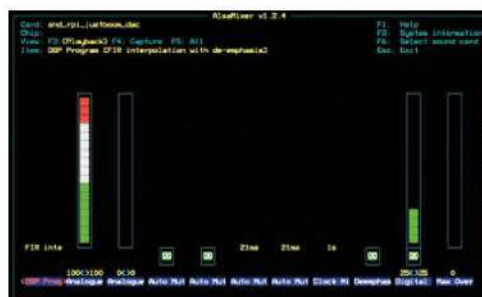
◄ When testing, use alsamixer to control volume

Raspberry Pi MIPI CSI/DSI connectors

Connecting cameras and displays to Raspberry Pi 5's new connectors

MAKER

Alasdair Allan

Alasdair Allan is a scientist, author, hacker, and journalist. In the past, he has mesh-networked the Moscone Center, caused a US Senate hearing, and contributed to the detection of what was – at the time – the most distant object yet discovered in the universe.

magpi.cc/docs

The CSI and DSI ports found on previous models of Raspberry Pi have been combined into two dual-purpose CSI/DSI (MIPI) ports on Raspberry Pi 5. These now use a denser connector pinout, previously only found on Raspberry Pi Zero and the CM4IO board. You can connect two displays, two cameras, or one camera and one display to these ports.

01 Attaching cameras

There is no configuration necessary for Raspberry Pi devices like cameras (**magpi. cc/camera**). If you plug a camera into either MIPI connector you will get an appropriate CSI connection, and your camera will be made available to the OS.
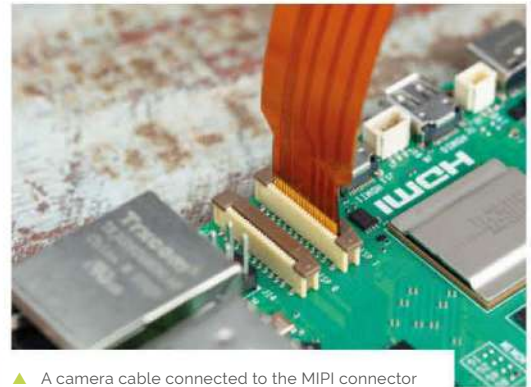
02 Camera cables

There are three Flat Flexible Cables (FFC) available to connect CSI cameras to Raspberry Pi 5:

- 200mm camera cable standard-to-mini
- 300mm camera cable standard-to-mini
- 500mm camera cable standard-to-mini

These camera adapter cables have a 22-way 0.5mm-pitch connection at one end (for Raspberry Pi 5), and a 15-way 1mm-pitch connector at the other (for your camera). You can buy Raspberry Pi 5 camera cables from The Pi Hut (**magpi.cc/ camcable5**). Note that these cables will only

work with Raspberry Pi Camera modules, and not the display. To this end, the cables have "CAMERA" printed on them

▲ A camera cable connected to the MIPI connector

03 Attaching a display

If you are using our 7-inch Touch Display with Raspberry Pi 5, it will not automatically be configured. You will need to add one of the following two lines to your **/boot/firmware/config. txt** file. Attaching the display to the CAM/DISP 1 connector, you should add:

```
dtoverlay=vc4-kms-dsi-7inch
```

Alternatively, by attaching it to the CAM/DISP 0 connector you can add the following line:

```
dtoverlay=vc4-kms-dsi-7inch,dsi0
```

The Camera and Display sockets are marked CAM/DISP 0 and 1. You can plug cameras and displays into either (or both) ports

The CSI/DSI ports are identical MIPI (MIPI (Mobile Industry Processor Interface) ports

❝ There is no configuration necessary for Raspberry Pi devices like cameras ❞

04 Available display cables

There are three Flat Flexible Cables (FFC) available to connect DSI displays to Raspberry Pi 5:

- 200mm display cable standard-to-mini
- 300mm display cable standard-to-mini
- 500mm display cable standard-to-mini

Like the camera cables, these cables have a 22-way 0.5mm-pitch connection at one end (for Raspberry Pi 5), and a 15-way 1mm-pitch connector at the other for your display. You can buy the cables from The Pi Hut (**magpi.cc/dispcable5**). The cables will have "DISPLAY" printed on them.

## 05 Using non-Raspberry Pi devices

If you are using a non-Raspberry Pi MIPI device – either a camera or a display – it will not be automatically configured for your Raspberry Pi 5. Instead, you will need to add a `dtoverlay` setting into the **/boot/firmware/config.txt** file to correctly configure the right port for the camera or display.

These dtoverlay settings should be provided by the manufacturer of your device. For example, adding `dtoverlay=ov9281` would configure an Omnivision OV9281-based camera on CSI/DSI1, while adding `dtoverlay=ov9281,cam0` would add the same camera to CSI/DSI0.

Top Tip 👍

Higher density

The Compute Module cable adapters can be used to connect standard cables to the higher-density mini connectors. See schematics (**magpi.cc/ cmcdaschematics**) and design files (**magpi.cc/ cmcdadesign**).
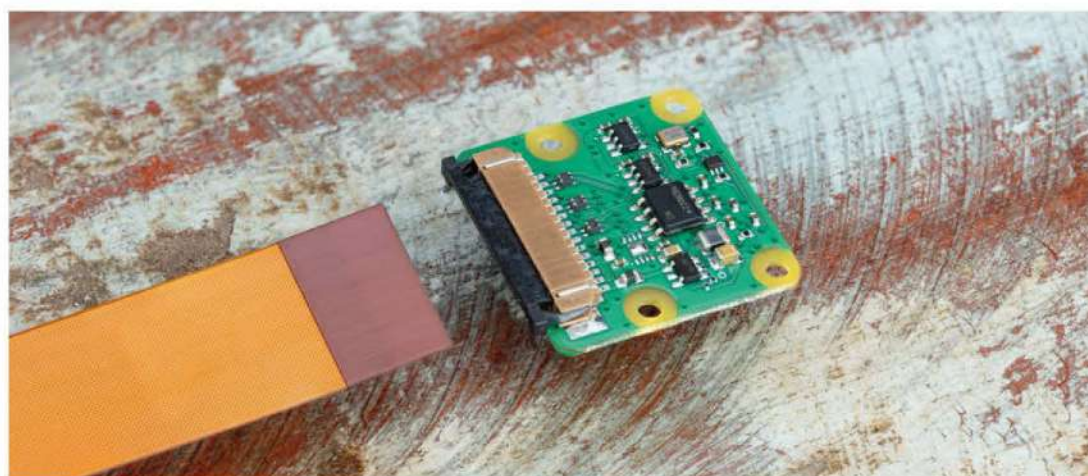
◀ The camera cables have a 22-way 0.5mm-pitch connection for Raspberry Pi 5 # and a 15-way 1mm-pitch connector at the other (for your camera)

#MonthOf Making 2024

GENIUS CONTRAPTIONS

Get making in March and share
your progress with the community!
By idle inventor **Rob Zwetsloot**

It's that time of the year again: **#MonthOfMaking.** A time when we want the community at large to make something and show it off. Whether you've never touched a resistor in your life or you're a pro with welding, nobody and nothing is off limits for #MonthOfMaking.

During March we're encouraging you to make your dreams a reality with your ultimate Raspberry Pi or Pico-based project. To that end, we've dug up some of the most over-the-top builds we could find – true Rube Goldberg machines that make use of Raspberry Pi technology to create the kind of useful chaos only homemade creations can achieve.

So fetch your Doc Brown wig, double-sided tape and some prototyping wire, and let's get inventing.

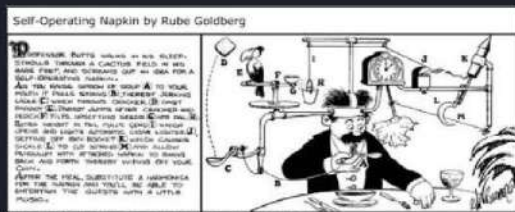## THE RULES OF #MonthOfMaking

> **Work on a project, new or old**

> **Take photos of your progress and completed projects**

> **Share it to social media with a helpful description**

> **Make sure to include the #MonthOfMaking hashtag**

> **That's it!**

RUBE GOLDBERG
MACHINES

Who is Rube and why do we keep making machines for them?

Even if you don't know the term for them, you very likely have seen a Rube Goldberg machine in cartoons, movies, or splashy adverts. They refer to elaborate, automated machines that perform a task – usually a simple one – with over the top chain-reaction mechanisms. Think a candle burning through a piece of string that releases a hammer to strike a ball into a tube that deposits the ball on a pulley system to lift up a blind.

They're named after an American cartoonist, famous for the weird and wonderful contraptions in his comics, though British cartoonist W Heath Robinson did the same thing earlier.

In an era before everything was part of the Internet of Things, weird gizmos that could turn on a light remotely or put your toast on were great fantasy fair, and the more elaborate and inefficient the funnier. Cartoons of the 1930s and '40s would often make use of them for fun animated effect, the board game *Mouse Trap* is based on the concept, and many inventions in Wallace and Gromit are also very Rube Goldberg-esque.

The concept lives on to this day, with silly machines going viral on all social media platforms as they use more varied and ridiculous ways of performing these simple tasks.

▲ One of Rube Goldberg's more famous early contraptions is this Self-Operating Napkin

▲ In the 1955 Tom and Jerry short 'Designs on Jerry', Tom dreams of becoming rich with his elaborate 'better mouse trap'

POWERHOUSE

In many *Merrie Melodies* and *Looney Tunes* cartoons, whenever a complex contraption or factory line is being illustrated, the song Powerhouse by the Raymond Scott Quintette was used to set the rhythm and atmosphere. It was usually a rearranged version by legendary composer Carl Stalling, and is still used in cartoons to this day. You can listen to the original recording here: **magpi.cc/powerhouse**

◄ The classic board game Mouse Trap has you build an elaborate device to capture a mouse – perhaps inspired by the Tom & Jerry cartoon?

ECCENTRIC
ENGINEERING
INSPIRATION

Build a better mouse trap, or just a very elaborate
way to turn on a light.

RUBE GOLDBERG MACHINE TO TURN ON A LIGHT

INVENTOR
ntewinkel | **magpi.cc/rubelight**

**YOU NEED TO TURN ON A LIGHT SWITCH,
BUT IT'S WAY OVER THERE!**
A woodpecker toy activates a robot arm, which
places a steel ball on a marble maze. This then
runs through the maze and lands on some
electrical contact points, which are used to move
a robot worm, which in turn jostles a robot
excavator to press start on the app for an Elegoo
car. This car pushes in a plug, which turns on a
robot, which then asks Alexa to turn the light on.
Alexa complies.

✳ **We recommend watching the full video.**
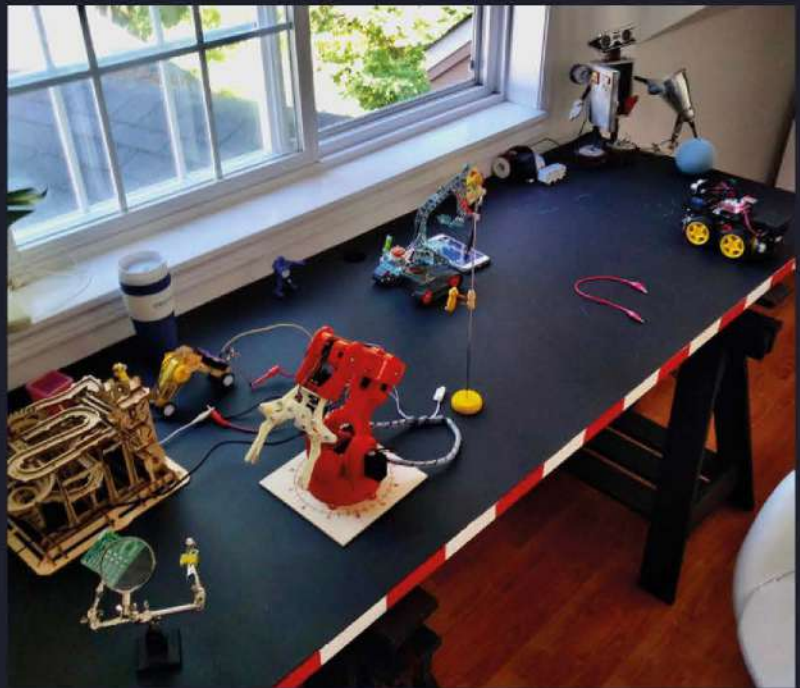
▲ The full device makes use of old and new technology, a perfect and efficient marriage

▼ Maybe not as large as your typical Rube Goldberg machine, but it's definitely a very complex way of reading a book
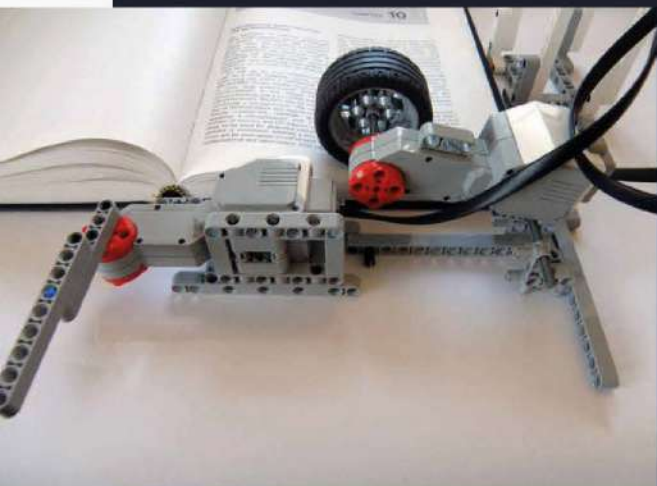
BrickPi Bookreader 2

INVENTOR
Dexter Industries | magpi.cc/brickbook2

YOU NEED TO TURN THE PAGES OF A PAPER BOOK TO MAKE IT INTO AN AUDIOBOOK

This contraption was built using BrickPi – a way for Raspberry Pi to interact with LEGO Mindstorms – and uses a wheel turn the book's pages, while a Raspberry Pi Camera Module uses OCR (optical character recognition) to read the text on the page, which is then converted into an audio file.

As the name suggests, this is the second iteration of Bookreader – the first one was able to read the text on an ebook reader, and included a mechanism to press the 'next page' button on the device. We're not sure if that, or using a tyre to turn the pages, is more silly.

▲ The tyre requires a lot of precision in its movement

## Sh*tty Dice Rolling, Dot-Counting Robot

INVENTOR
DelfinGuy | magpi.cc/diceroller

YOU NEED TO MANUALLY ROLL SOME DICE AND READ THE OUTCOME

This moving rig was created out of recycled cardboard, and can be flipped up and down by a servo motor to manually roll some dice.

A Raspberry Pi Camera Module is set in a position to read the dice when they settle, then computer vision is used to count the pips on the dice, and even keep a tally.
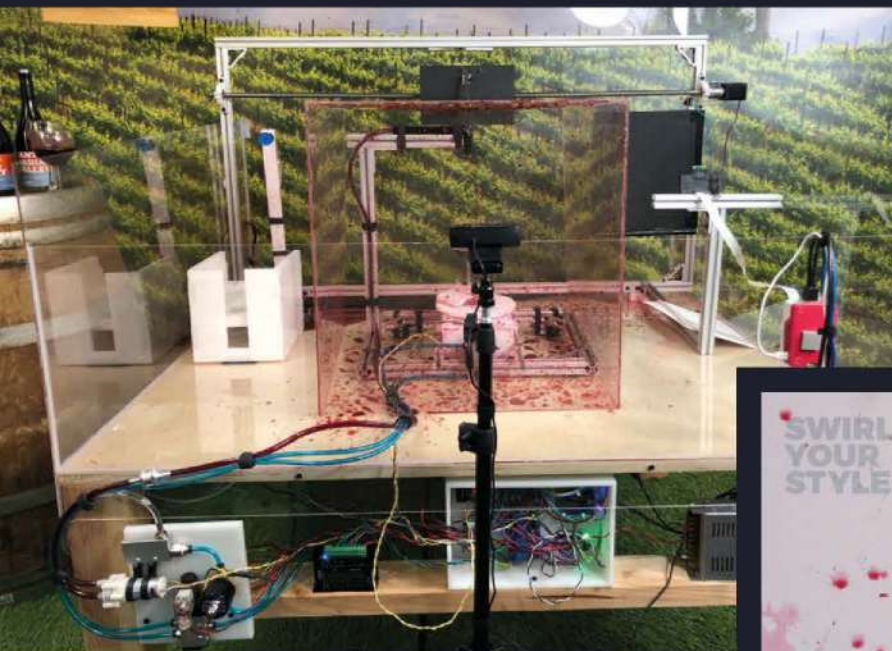
We love the upcycling and recycling involved with this project.
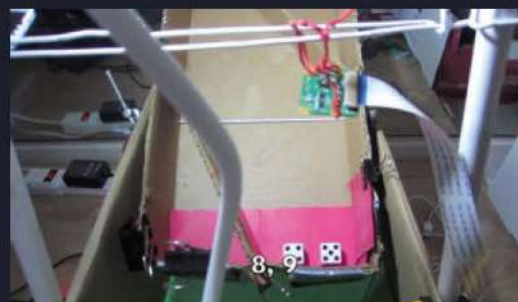
▲ No human could possibly count the outcome of the dice here

▲ The full contraption, made with cardboard, paper clips, duct tape, coat hangers, and some electronics

The Swirl Machine

INVENTOR
KPS3 | **magpi.cc/swirlmachine**

HOW DO YOU CREATE WINE ART?

A robot arm picks up a piece of paper, and then sticks it to a rig. It then fills up a glass of wine (to a user-specified amount) with a pump, and then spins it really *really* fast (also user-specified) on a motorised spinning platform. The wine will then splash on the paper, which the robot arm will take to a final station where it's photographed and analysed to determine the user's personality.

This was a marketing stunt for a winery, and unfortunately this machine is no longer operational. We can assure you it was very cool and funny to see in action though.

▲ The full device is thankfully contained in a perspex box to limit the amount of wine spillage

◀ Our art from the time the machine was running. We can't remember how it determined out personality but it was probably 'very cool and funny'
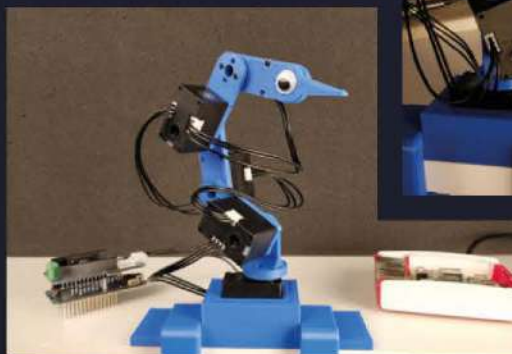
Robot Arm Clock

INVENTOR
Hendrik Ohrens | **magpi.cc/roboarm**

YOUR CLOCK HAS BROKEN

This time machine uses a robot arm to manually move the hands of the clock as time passes. Raspberry Pi keeps it ticking, and makes sure the hand is moved at the right time. The googly eye is very important, so that you can humanise the robot helping you keep time.

The robot arm is custom made with 3D-printed parts, and has had lengthy training to properly move the hands.
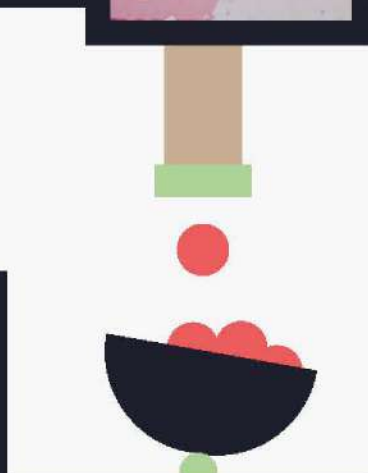
▲ A custom 3D printed robot arm, making use of Raspberry Pi and Arduino

◀ How clocks worked before the creation of this robot arm, nobody knows

The CD's eject motor gets a workout by pushing food into the mouth of a hungry cup/hamster
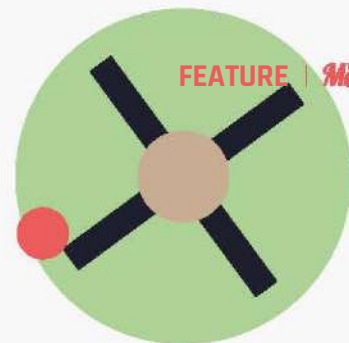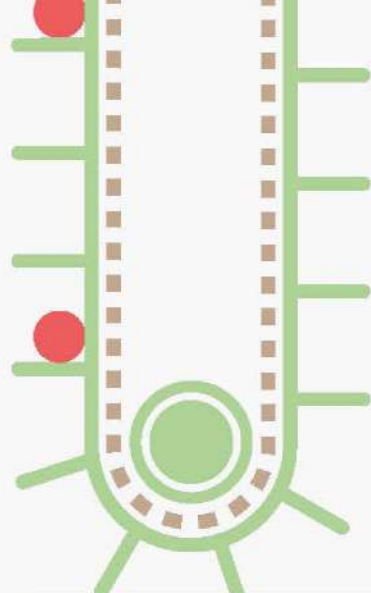
Hamster feeding CD-ROM

INVENTOR
Akkie | magpi.cc/akkiecd

YOUR HAMSTER IS HUNGRY
This controls a CD drive with a Raspberry Pi to remotely activate the eject command. As the tray moves out, it pushes a load of hamster food into a receptacle. Akkie is well known for his ejecting CD drive tricks – he had it ring a bell for new year, turn on an air conditioinig unit whose remote has broken, and he would wear one that was remotely controlled by his smart phone on a hard hat. What did it do on his hat? Eject.

Safety first!

When building ridiculous contraptions, make sure to stay safe. Good inventors have gear like safety glasses, gloves and face shields, and don't mess with mains electricity. If you're under 18, get a parents help with any power tools.

Build your skills

Every build can be a learning experience. While we've definitely felt the disappointment of a project not quite working, you can always learn from your mistakes and failures. It's all part of learning how to make!

Where to share!

Posting on Instagram, Threads, or Mastodon with the hashtag #MonthOfMaking is the best way to share your builds. Otherwise, we'll be making posts on our Facebook page that you can comment on with images, and if you don't do any social media you can always email us.

Facebook › **facebook.com/MagPiMagazine**

Mastodon › **magpi.cc/mastodon**

Threads › **@magpimagazine**

Instagram › **@magpimagazine**

Email › **magpi@raspberrypi.com**

FROM THE MAKERS OF *The* MagPi THE OFFICIAL RASPBERRY PI MAGAZINE

NEW 2024 UPDATE

START

WINNER

PLAY & CODE GAMES!

RETRO GAMING
WITH
RASPBERRY PI
3RD EDITION

+ BUILD AN ARCADE MACHINE

180 PAGES OF
VIDEO GAME PROJECTS

File manager
Change color
Change icon
Extra blocks
Save dump
Load dump
Hexeditor
Defragment
Reformat

/ : Select
: OK
: Cancel

Display the list of the files found in
the selected VMU.

RETRO GAMING
WITH
RASPBERRY PI
3RD EDITION

Retro Gaming with Raspberry Pi shows you how to set up Raspberry Pi 5 to play a new generation of classic games. Build your gaming console and full-size arcade cabinet, install emulation software and download original games with our step-by-step guides. You'll discover a vibrant homebrew scene packed with new games for original consoles and legal access to all those retro games you remember!

- *Set up Raspberry Pi for retro gaming*

- *Emulate classic computers and consoles*

- *Learn to code retro-style games*

- *Build a console, handheld, and full-size arcade machine*

NVMe **Base**

SPECS

FEATURES
Works with most NVMe M.2 SSDs; Flat flex PCIe cable; Standoff kit; 4 × rubber feet

CONNECTIONS
M.2 Key slot, PCIe slot (18-pin)

Give your Raspberry Pi 5 a major storage speed boost with this PCIe M.2 SSD adapter. By **Phil King**

▼ The NVMe Base comes with a standoffs kit, flat flexible PCIe cable, and four rubber feet

The NVMe Base enables you to connect an NVMe (non-volatile memory express) solid-state drive to Raspberry Pi 5's PCIe slot for storage with far faster read/write speeds than a microSD card.

Rather than coming in the HAT form factor to sit on top of Raspberry Pi, it fits underneath, hence the "Base" moniker. This means it doesn't obstruct a cooling fan, if you're using one, nor tie up the GPIO pins, so you can still add another HAT on top.

Before attaching the NVMe Base to the underside of Raspberry Pi 5 using the supplied standoff kit – demonstrated in Pimoroni's installation video (**magpi.cc/nvmebaseyt**) – you'll want to insert your NVMe SSD stick into the Base's M.2 key slot. The board is long enough to accommodate 2280 size SSDs, and has mounting holes for this plus 2230, 2242, and 2260 drives – so you can secure it with a bolt and nut.

Securing the Base

The next step is to attach M2.5 standoffs to the top of the Base using the four mounting holes. The kit helpfully includes both short and long bolts – the latter are useful if you want to securely mount another HAT on top of Raspberry Pi 5.

Connecting the Base's PCIe slot with the one on Raspberry Pi 5 is done using a small, flat S-shaped cable that flexes and has labels to help you orient it correctly – the end for the Base is slightly wider, at 18 pins. It's easier to connect Raspberry Pi 5's PCIe slot first, then the Base's, due to the latter's less fiddly flip tab. You can then fold
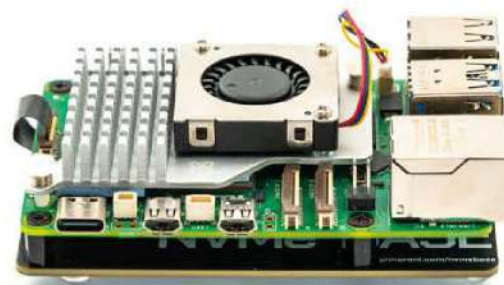
▲ The slimline NVMe Base fits snugly under Raspberry Pi 5, secured by bolts and standoffs

▼ A short flexible cable connects the NVMe Base to Raspberry Pi 5's PCIe slot

❝ We achieved a write speed of 514MB/s and a read speed of 858MB/s ❞

▼ The underside of the NVMe Base board, secured to Raspberry Pi 5 with bolts and standoffs

the flexible cable over so the Base is underneath Raspberry Pi 5 to form a sandwich, before using a small screwdriver and bolts to secure it. The only downside is that the extra height means it won't fit in a standard case.

With the hardware installed, you're ready to start using your SSD… that is, once you've checked that your system is up to date and you have the latest bootloader version selected in raspi-config: Advanced Options > Bootloader Version > Latest, then select 'No' and reboot. The drive should then appear in the /**media** directory, and be shown by the lsblk command. If not, make sure it is formatted (you can use Raspberry Pi Imager).

Drive compatibility

While the majority of NVMe M.2 drives should work fine, Pimoroni's product page notes that a few models have quirks or have proved troublesome. The safest option is to choose a tested model listed there, or purchase the NVMe Base bundled with a compatible 250GB or 500GB SSD.

Raspberry Pi 5 officially only supports the Gen 2.0 version of PCIe, but adding an extra line to /**boot/config.txt** will force Gen 3.0 for extra speed.

In our tests, using the `dd` command, we achieved a write speed of 514MB/s and a read speed of 858MB/s. While far from our SSD's maximum (due to only using one of its PCIe lanes), it's still many times faster than microSD (typically around 30MB/s write, 90MB/s read), and also better than an SSD connected via speed-limiting USB. Check out Pimoroni's own tests on various SSDs at **magpi.cc/nvmebasetests**.

You'll want to make Raspberry Pi 5 boot from the SSD instead of the microSD card. This is easily achieved by writing the OS to it with Raspberry Pi Imager and then selecting Advanced Options > Boot Order > NVMe in raspi-config. For our drive, this cut around four seconds from the average boot time. We also noticed that some apps, such as Chromium, seemed a little snappier. ❚

Verdict

A slimline adapter that sits neatly under Raspberry Pi 5 and enables fast PCIe read/write speeds with a suitable SSD.

9/10

Argon ONE V3
M.2 NVME Case

▶ Argon40 ▶ **magpi.cc/argononev3** ▶ £40 / $49

Argon's legendary case gets a Raspberry Pi 5 upgrade with built-in NVMe storage capability. **Lucy Hattersley** builds her dream computer

Argon40 has made a name for itself amongst the Raspberry Pi community by making high-quality cases that transform our favourite single-board into a professional-looking computer, or a smart feature-packed media player.

This month we have the hotly anticipated Argon ONE V3 M.2 NVMe PCIe Case. Hopes are high for this one and we can tell you it hits home runs all the way. Redesigned for Raspberry Pi 5 this board combines the features of the Argon ONE V2 with the – previously separate – M.2 Expansion Board add-on to create an all-in-one computer case with super-fast, and super-large, storage that also cleverly uses passive cooling and heatsinks to keep everything running. This is the one we have been waiting for.

All together now

The Argon ONE is Argon40's flagship case, containing a daughterboard for Raspberry Pi that adds additional features such as full-sized HDMI sockets and an infrared (IR) receiver.

On the base of Argon ONE V3 is a removable cover that provides access to the M.2 NVMe socket. Here you can insert any M.2 NVMe with M-Key up to 2280 size. The flap is marked "THERML" which nods to its aluminium heatsink and a long strip of thermal pad is included to transfer the heat out into the case.

Two more silicon pads are included to connect Raspberry Pi's CPU and PMIC (Power Management Integrated Circuit) to the case.

Alongside this impressive passive cooling is a redesigned 30mm fan and blower. This is repositioned at an angle to be "more efficient and quiet", and we found it unobtrusive even when stress testing.

Argon ONE V3 now sports Raspberry Pi's RP2040 microcontroller to control various functions like fan speed and power management (via jumper pins on the daughter board). The power button is less of a novelty now that Raspberry Pi 5 itself features one. However, the presence of a 3.5mm audio jack will be a welcome addition for audio buffs now that it has been removed from Raspberry Pi 5's main board.

One advantage over the Argon ONE V2 board is that the M.2 NVMe now connects directly to the PCIe socket on Raspberry Pi 5. This leaves all four USB-A sockets available.

A removable magnetic flap on top of the case provides access to repositioned GPIO pins alongside a handy pinout guide.

Assembly and testing

Putting together the Argon ONE V3 was a relatively painless process thanks to the included assembly instructions (**magpi.cc/onem2man**). Raspberry Pi


▶ Argon ONE V3 is a neat case made from a black aluminium alloy that helps dissipate heat

◀ Underneath Argon ONE V3 is a removable thermal heatsink to fit the M.2 NVMe drive. Here we can also see the power button, full-sized HDMI slot, 3.5mm audio jack and Raspberry Pi 5 ports

▼ Heat testing Raspberry Pi 5 inside the Argon ONE V3 showed it took five minutes (300 seconds) to reach the 60°c point, where the fan started, and remained there for the rest of the 15-minute (900-second) test. At no point was speed throttled
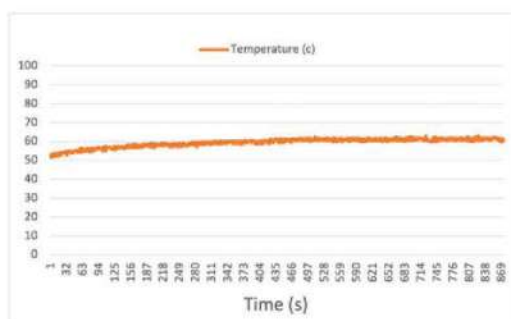
5 is connected to the HDMI daughterboard, and the PCIE cable is used to connect the bottom half of the case to Raspberry Pi 5. Then the whole thing is screwed together. Finally, the M.2 NVMe storage is connected to the underside making it possible to upgrade the drive without opening the whole case.

As with previous Argon ONE cases, the microSD card is hidden away and can't be used without opening up the case. This is less problematic these days as a USB thumb drive flashed with Raspberry Pi OS can be used to run Imager and flash the storage drive. Attach an Ethernet cable and you can also use Network Install with Raspberry Pi 5 (**magpi.cc/networkinstall**).

Speed-testing of the NVMe drive tells you much more about the quality of your drive than the case itself. We used a 500GB WD Blue storage stick and measured the speed using Raspberry Pi OS's built-in Raspberry Pi Diagnostics tool to test performance. It returned a sequential write speed 789590 KB/sec (790 MB/s) almost 80 times faster than the recommended pass speed for a microSD card. It's fast.

The heat test is also interesting. We used `stress --cpu 4` and measured the output with the script found at **magpi.cc/thermaltesting** for 15 minutes.

Raspberry Pi 5 inside the Argon ONE V3 case idles at around 54°c (down from the 65°c baseline of an uncooled Raspberry Pi 5 without a heatsink). We found the fan kicked in at the 60°c mark after five minutes and kept the Raspberry Pi 5 hovering around 61°c for another 10 minutes. At no point did Raspberry Pi OS reach the 80°c mark where performance throttling begins. It compared favourably to a Raspberry Pi 5 and an official Active Cooler unit.

> ❝ An all-in-one computer case with super-fast, and super-large storage ❞

Put it to use

One optional extra we should mention is an internal Argon ONE BLSTR DAC audio board upgrade, which will be sold separately. Alongside the 3.5mm jack this will make Argon ONE V3 ideal for audio fans. We didn't have one for testing and can't see it on the Argon40 website just yet, so hopefully that will come down the line.

All of this transforms Raspberry Pi 5 from a hackable board to a desktop computer. A role our favourite computer is increasingly fulfilling with aplomb. The built-in infrared connection, large storage, and full-sized HDMI connection also ensure Argon ONE V3 becomes the perfect media player or home games console. This case is highly recommended. ◾

Verdict

An excellent case that sees a lot of Argon's ideas reach fruition. Turn your Raspberry Pi 5 into a smart desktop computer, media player, games console or DAC audio player.

10/10

ED-HMI3020

▶ EDATEC ▶ **magpi.cc/edhmi3020** ▶ From £212 / $268

An industrial touchscreen panel powered by Raspberry Pi 5. By **Phil King**

◀ With a rugged housing and Raspberry Pi on the rear, this is no ordinary touchscreen tablet

Designed for industrial settings, the **EDI-HMI3020 touchscreen panel has a ruggedised housing with a well-protected Raspberry Pi 5 mounted on the rear, cooled passively with a heatsink.** It comes in 7-inch (1024×600 pixels) and 10-inch (1200×800) variants with 4GB or 8GB or RAM. We tested out the 8GB, 10-inch model.

❝ You can use the M.2 socket inside to add an NVMe 2230, 2242, or 2260 SSD ❞

While there's no direct access to Raspberry Pi 5's GPIO header via the case, the four USB ports are exposed, along with the USB-C power socket, two micro-HDMI ports, microSD card slot, and an Ethernet port with optional PoE functionality.

An upgrade over the HMI3010 models, the HMI3020 adds RS232 and RS485 interfaces, as well as 3.5mm headphone and mic jacks. The key addition, however, is an M.2 socket. To access it, you'll need to unscrew Raspberry Pi 5 and the case from the rear of the unit, then you can use the M.2 slot inside to add an NVMe 2230, 2242, or 2260 SSD.

Touch control

Our unit's microSD card had Raspberry Pi OS Bookworm pre-installed with the drivers for the ten-point touchscreen, which worked instantly upon bootup. As we've found with other Raspberry Pi touchscreens, there's no right-click functionality by default and we also couldn't double-click files to open them (so had to enable one-click opening in the File Manager). There was no on-screen keyboard available either, though we managed to get one running with a workaround from the Raspberry Pi forums: **magpi.cc/bookwormkb**.

The EDI-HMI3020 also comes with an optional 8MP front-facing camera – a Camera Module V2 – for video conferencing and suchlike, making it a versatile touchscreen tablet.

Verdict

A robust touchscreen panel with well-protected Raspberry Pi 5 mounted on the rear and the option to add an M.2 SSD.

8/10

◀ Mounted on the rear, Raspberry Pi 5 has its main ports accessible through the rugged case

10 Amazing:

Raspberry Pi 5 accessories

Power up your Raspberry Pi 5 with these excellent add-ons

Raspberry Pi 5 has been out for a while now, which means there are several add-ons and expansions for it already. Along with the HAT+ specification we talked about last issue (**magpi.cc/138**), we expect to see some great new kit in the future. Here are ten of the best add-ons you can get for your Raspberry Pi right now.

▲ Raspberry Pi Active Cooler

Minimal cooling
A little clip on heatsink and blower that will keep your Raspberry Pi 5's processors cool while still leaving full access to the board.

magpi.cc/activecooler | £5 / $6

▲ Raspberry Pi 27W USB-C Power Supply

Maximum juice
Raspberry Pi 5 can get a little power hungry, and this higher-capacity PSU makes sure it's always fed.

magpi.cc/psu | £12 / $15

◄ Official case

Officially safe
This simple case not only keeps your Raspberry Pi nice and contained, it also has a blower fan inside and a removable lid to access the GPIO pins

magpi.cc/case | £10 / $13

▼ Raspberry Pi Camera Cable

Photo converter
To accommodate space on the board, Raspberry Pi 5 uses an FPC connector for Camera Modules, so you'll need a converter to get an existing camera snapping pics

magpi.cc/fpccable | £1 / $1

▲ Raspberry Pi RTC Battery

Right on time

If you need precision timing on your Raspberry Pi 5 and cannot rely on an internet connection, using this in conjunction with our tutorial from issue 138 (**magpi.cc/138**) will help you out.

magpi.cc/rtcbattery | £5 / $6

▼ Pibow Coupe 5

Slimline case

An update to the original Raspberry Pi case line not only protects a Raspberry Pi 5 but also has space for the active cooler, and access to the on-board ports.

magpi.cc/pibow5 | £10 / $13

▼ Argon ONE V3 M.2 NVME

Beefy desktop

A powerful protective shell for Raspberry Pi that reroutes ports, gives access to the GPIO, and lets you install an M.2 NVMe SSD drive.

magpi.cc/argononev3 | £46 / $58

▲ NVMe Base

Add storage

If you can't wait for the official M.2 HAT+ then there's always the Pimoroni-made NVMe Base, which slots underneath.

magpi.cc/nvmebase | £14 / $18

▼ KKSB Case

Tablet vibes

This nifty case allows you to quickly and conveniently combine Raspberry Pi 5 with the official touchscreen so you can easily use your Raspberry Pi 5 on the go.

magpi.cc/kksb5 | £35 / $44

▼ Cover for Active Cooler

Moderate protection

A cool little acrylic cover for your Raspberry Pi Active Cooler, and for some of your Raspberry Pi 5 too. It comes in several colours.

magpi.cc/coolercover | £3 / $4

Learn AI
with Raspberry Pi

Discover more about the hot topic of AI with these resources.
By **Phil King**

The Coming Wave

AUTHOR

Mustafa
Suleyman

Price:
£25 / $33

**magpi.cc/
comingwave**

Artificial intelligence is the current buzzword thanks to the recent arrival of impressive online tools such as ChatGPT, Google Gemini and Meta Llama. You may well have played with these chatbots, but AI can do a lot more and has the potential to change all of our lives – for good or bad.

This brave new world is explored in *The Coming Wave* by Suleyman, the co-founder of the DeepMind AI company (now part of Google). On the one hand, he argues, AI has great potential to diagnose diseases and discover new drugs. It could also transform agriculture, solve the climate crisis, and lead to greater prosperity.

On the downside, AI may also be used for nefarious purposes to unleash havoc on the world that may threaten livelihoods and nation states. Suleyman outlines ten steps to help contain AI's excesses in the closing chapter of this fascinating overview.
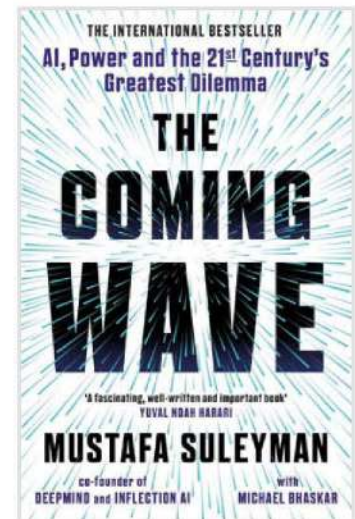
Further reading
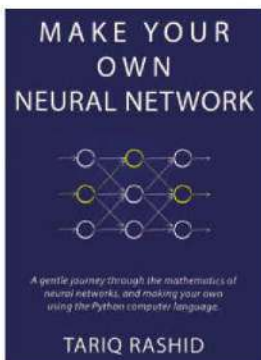
Books to help
you learn more
about AI

MAKE YOUR OWN NEURAL NETWORK
With Python code examples, Tariq Rashid's book gently guides newcomers through the world of neural networks inspired by the human brain.
▶ **magpi.cc/makeneural**

HELLO WORLD
Professor Hannah Fry has written a fascinating book about the impact AI

is having on every aspect of our lives, and where it might go next.
▶ **magpi.cc/hwbook**

ARTIFICIAL INTELLIGENCE FOR HUMANS
Free on GitHub, Jeff Heaton's trilogy gives a practical introduction to AI, covering fundamental and nature-inspired algorithms, deep learning, and neural networks.
▶ **magpi.cc/aiforhumans**

Introduction to Machine Learning and AI

AUTHOR
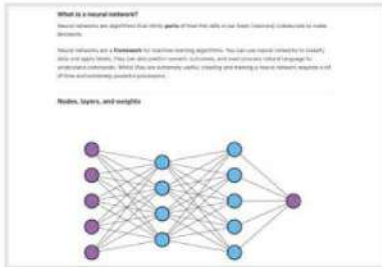
Raspberry Pi Foundation

Price:
Free

magpi.cc/edxrpiai

Available via edX for free (or paid with optional certificate), this four-week course was created by the Raspberry Pi Foundation in collaboration with Google DeepMind and "aims to help young people understand how AI works and how it is changing the world".

Each weekly module comprises a mixture of text and video resources, along with a few practical examples to get hands-on. The first week introduces AI and machine learning and what they can be used for, such as data classification.

Week two covers what problems AI can solve, preparing data for machine learning, and potential problems. The third week delves into the machine learning process, supervised learning including decision trees and nearest neighbour, and unsupervised and reinforcement learning. The final week covers the workings of neural networks using nodes and connections. 🄼

Beginning Artificial Intelligence with the Raspberry Pi

AUTHOR
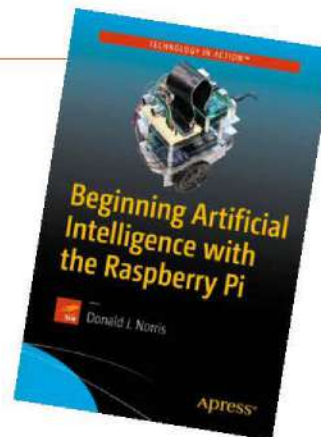
Donald J Norris

Price:
£28 / $30

magpi.cc/ beginaibook

If you want to get hands-on using AI in Raspberry Pi projects, this book is a great starting point. While it's a little old now (2017) and some code libraries used are deprecated, it covers the basics from a practical perspective.

After an overview of AI, it introduces basic concepts such as Boolean algebra and inference. The third chapter is where it gets practical, offering some expert system demonstrations that can be run on Raspberry Pi, including animal identification. It then moves on to creating games, including strategy classic *Nim*.

Further chapters cover – in detail, with example projects and Python code – fuzzy logic, machine learning, neural networks, deep learning, evolutionary computing, and behaviour-based robotics. Some of these projects involve using an 'Alfie' robot car – build details are in an appendix. 🄼

Online courses

Enrol in an AI web course today

SELF-DRIVING CARS WITH DUCKIETOWN
Build your own wheeled robot and use AI and computer vision to get it to drive autonomously around a 'Duckietown' miniature city.
▶ **magpi.cc/duckietown**

AI FOR EVERYONE
This free course on Coursera is easy to follow for newcomers, mainly comprising videos. Topics include building projects and the impacts of AI.
▶ **magpi.cc/aieveryone**

ARTIFICIAL INTELLIGENCE NANODEGREE
A beginnner-to-intermediate programme from Udacity that comprises six main courses covering topics such as search methods and automated planning.
▶ **magpi.cc/udacityai**

Tim
Stenning

The Raspberry Pi Store is filled with people knowledgeable and passionate about what they do – including Tim, one of the original store employees

> **Name**   **Tim Stenning** | > Occupation   **Shop Floor Manager**
> **Community role**   **Customer help** | > URL   **raspberrypi.com**

▼ Tim joined the team at SiliCon in San Jose to help show off what Raspberry Pi Pico can do

The Raspberry Pi Store in Cambridge's Grand Arcade recently celebrated being open for five years – quite a feat for a store that started off life as a pop-up. One of the keys to its success was bringing in experienced electronics retail staff from the recently defunct Maplin, including Tim Stenning.

"Not too long after Maplin closed I was approached by my manager [Oli Wilkin], who I had helped with the closing of the stores in Cambridge," Tim tells us. "Remembering not having the chance to look at Raspberry Pi at Maplin, and [it] being a tech-centred experience, I took the opportunity and joined the team. Now, just over five years

on since the opening of the first store, I'm finding that I'm still learning something new every day on the job."

What kind of customers do you see at the store?
We see customers from all backgrounds and countries visiting the store, from those with no experience, families looking to engage their children with coding, to hobbyists, tinkerers and die-hard makers.

[Aside from the pop-ups,] it's the only official Raspberry Pi Store in the world. As you could imagine this drew interest from makers from all over the world. One notable visit during our first month open in 2019 was a couple who flew in from South Africa just to experience Raspberry Pi in retail.

What are some of the most frequently asked questions?
We get a variety of questions every day, ranging from some very common to very niche use cases. Because of the wide variety of different uses of Raspberry Pi and its accessories, there's never

▲ The store staff are very friendly and can help you find what you're looking for

◀ The store has been around for five years now – how time flies!

▼ Don't forget to pick up a copy of *The MagPi* and *HackSpace* magazine when you're in the store!

❝ We get a variety of questions every day ranging from some very common to very niche use cases ❞

any dumb or wrong questions, and we always encourage people to ask us questions.

Some of the most common ones are:

- What is a Raspberry Pi and what can you do with it?
- Can you play *Minecraft* / *Roblox* / games on a Raspberry Pi?
- Do you have Raspberry Pi CM4 / Zero / 3 / 4 / 5 models in stock?

Do you have a good story about helping someone out with a purchase?

There are a fair few stories as we try to be as inclusive as possible to everyone visiting the store, and try to provide assistance and the best recommendations possible

depending on individual needs. However, the one that stands out the most for me would be when a visually impaired Raspberry Pi fan and maker asked for assistance with the products and guidance around the store.

I was happy to oblige, and walk the customer through the store and provide explanations for the range of products available. I'd like to think that the customer was provided with all the information they needed to get their project working.

What's you're favourite Raspberry Pi product?

My personal favourite official Raspberry Pi product would be the Raspberry Pi Camera Module 3. With the use of the Picamera2 library there are

so many ways to take advantage of the functionality of the cameras capabilities which only get better with the use of Raspberry Pi 5. In-store, we've tested and demonstrated simple tasks like taking pictures to more complex multiple camera setups, AI and object recognition. ▥
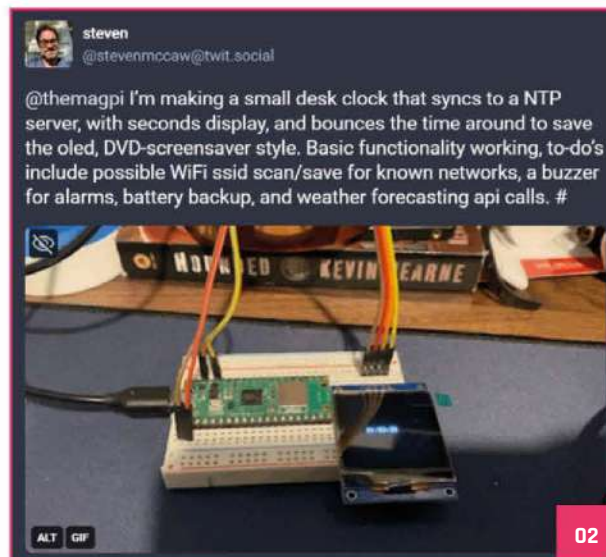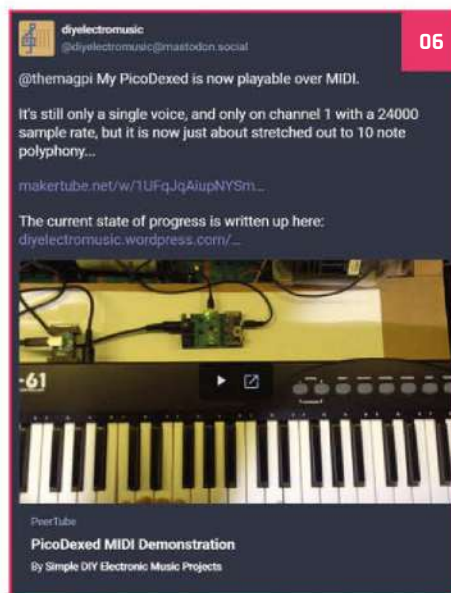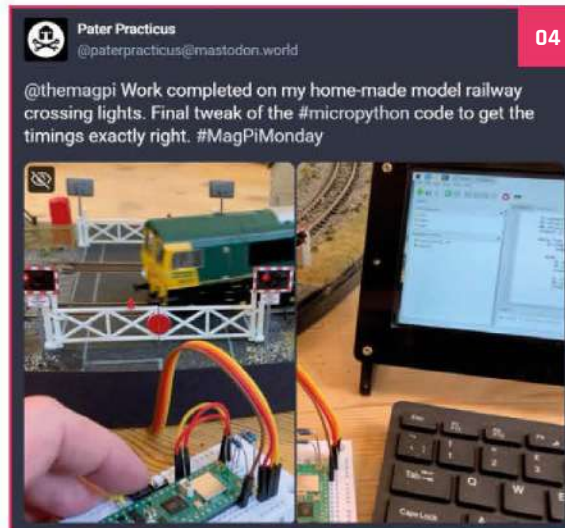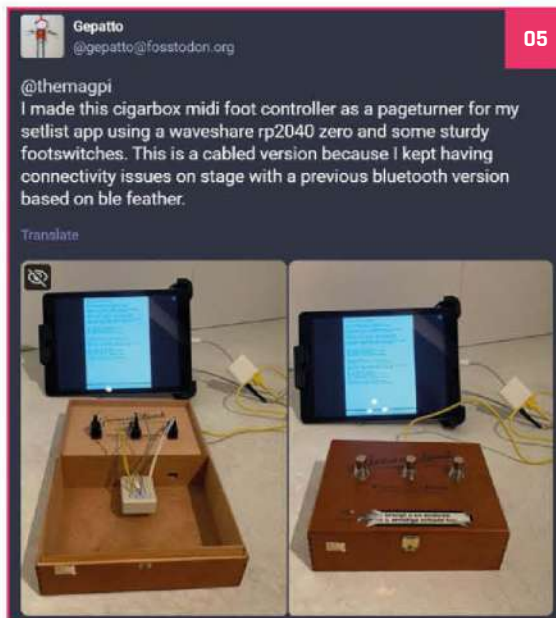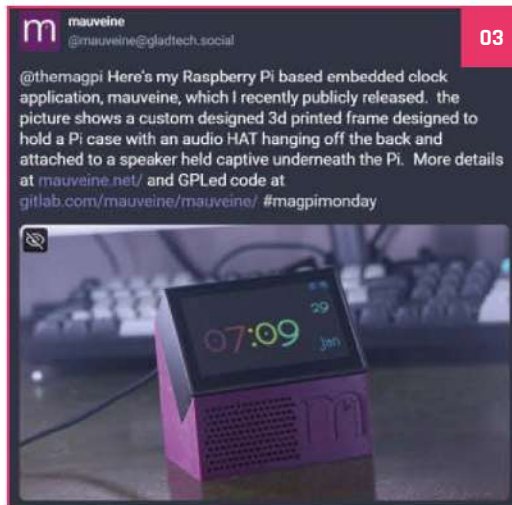
MagPi Monday

Amazing projects direct from social media!

Every Monday we ask the question: have you made something with a Raspberry Pi over the weekend? Every Monday, our followers send us amazing photos and videos of the things they've made.

Here's a selection of some of the awesome things we got sent this month. Remember to follow along at the hashtag #MagPiMonday!

01. We get some great submissions on Mastodon from serious tinkerers.

02. A cute way to use the video output capabilities of Raspberry Pi Pico

03. We often think about making little clock assistants to keep around the home, something like this

04. Combining hobbies is great, especially when you can use a Pico to enhance your other hobby

05. A good upcycle of a lovely wooden box! We hope the buttons can survive a foot press!

06. Editor Lucy might like this one – last we saw her she was playing around with a MIDI key-board to some success

07. For a first 3D print, this gets a big thumbs up

08. An interesting fusion! We hope the two play nice together

Chris Burton
@burtyb@widget.uk

@themagpi I've been working on the software (using Pico C SDK) for a Pico based cable tester. It's a bit bulkier compared to my old SAMD21 version but a lot easier to put together 😬.
#MagPiMonday

steven
@stevenmccaw@twit.social

@themagpi I'm making a small desk clock that syncs to a NTP server, with seconds display, and bounces the time around to save the oled, DVD-screensaver style. Basic functionality working, to-do's include possible WiFi ssid scan/save for known networks, a buzzer for alarms, battery backup, and weather forecasting api calls. #

mauveine
@mauveine@gladtech.social

03

@themagpi Here's my Raspberry Pi based embedded clock application, mauveine, which I recently publicly released. the picture shows a custom designed 3d printed frame designed to hold a Pi case with an audio HAT hanging off the back and attached to a speaker held captive underneath the Pi. More details at mauveine.net/ and GPLed code at gitlab.com/mauveine/mauveine/ #magpimonday

Pater Practicus
@paterpracticus@mastodon.world

04

@themagpi Work completed on my home-made model railway crossing lights. Final tweak of the #micropython code to get the timings exactly right. #MagPiMonday

Gepatto
@gepatto@fosstodon.org

05

@themagpi
I made this cigarbox midi foot controller as a pageturner for my setlist app using a waveshare rp2040 zero and some sturdy footswitches. This is a cabled version because I kept having connectivity issues on stage with a previous bluetooth version based on ble feather.

Translate

diyelectromusic
@diyelectromusic@mastodon.social

06

@themagpi My PicoDexed is now playable over MIDI.

It's still only a single voice, and only on channel 1 with a 24000 sample rate, but it is now just about stretched out to 10 note polyphony...

makertube.net/w/1UFqJqAiupNYSm...

The current state of progress is written up here:
diyelectromusic.wordpress.com/...

PeerTube
PicoDexed MIDI Demonstration
By Simple DIY Electronic Music Projects

Pater Practicus
@paterpracticus@mastodon.world

@themagpi My first ever 3D design printed - a screen surround for my video-call interruptibility status indicator. The fit was absolutely perfect. Now to work out the back half of the case for the #raspberrypi Pico etc. #MagPiMonday

07

esccrasciyt

3 w ...

Well, what if I made my own Pico? Meet Picuno, the child of the 2040 and the Uno. All pins mapped out, more storage and of course micropython and circuitpython compatible. Fully opensource too. esccrasci.in/Picun... MagPiMonday

08

Events in pictures:
Raspberry Pi Day 2023 in Cameroon

Community and official events in the wild

Raspberry Pi Days are events run in Cameroon for people to learn about and discuss working with Raspberry Pi – this event at the end of 2023 also allowed attendees to experience Raspberry Pi 5 as well.

01. The event is held in a university classroom

02. Several Raspberry Pi 5 boards were present for folks to have a look at

03. Different capabilities of Raspberry Pi are explored in these events

FIND OUT ABOUT NEXT MONTH'S EVENTS ON PAGE 92

02

01

03

Crowdfund this

Great crowdfunding projects this month

Doly

Billed as a companion robot, Doly uses a Raspberry Pi Compute Module 4 and features a lot of open hardware and software allowing you customise it as you wish. It's a little trundly robot with expressive eye screens. Its creator tells us you'll be able to upgrade it, and even use it for education.

▶ **magpi.cc/doly**

PiWings 2.0

SB Components is back with a new drone platform powered by Raspberry Pi Pico that can also work with ESP32 S3. It includes an integrated MPU6050 IMU which the creators say will allow for accurate orientation and a smooth flight.

▶ **magpi.cc/piwings2**

Your Letters

RAM check

How do you check the RAM size of a Raspberry Pi, and what were the RAM variations released for Raspberry Pi 3 Model B+?

Mahender via email

You're in luck, for Raspberry Pi 3B+ only the 1GB version was released. Multiple RAM types started with Raspberry Pi 4, however there are also a couple of variations on original Model B hardware.

On Raspberry Pi 5 it will say on the board how much RAM it has (there's a little resistor soldered next to the number) and on other Raspberry Pi boards you can check by opening the terminal and using:

```
$ cat /proc/cpuinfo
```

This will give you a revision code, which you can check against this list: **magpi.cc/revcodes**

▼ The numbers on the board represent the amount of RAM, with a resistor soldered next to the board's onboard RAM

Image captions

We really enjoy our *MagPi* subscription – thanks for all the great issues.

There's a super-minor niggle that I'm hoping you can address in future issues. In some (not all articles this year) you don't label your photos. Now if it's a graphic illustration fair enough, but increasingly we're seeing unlabelled photos where it doesn't make sense. Sometimes the photo is nonsensical (such as a graph for 'photon torpedos' or 'wibbly lines'), other times the photos relate to the article but aren't labelled to explain what they are illustrating.

Usually, *The MagPi* labels the photos in articles, which is also great for accessibility. Even when relevant photos aren't available, if they are to be presented in the style of relevant images, perhaps photos should have a 'photo for illustrative purposes only' caption to save readers the time of trying to figure out their significance.

Luke via email

You're absolutely right – the example you sent us was a case study that does not usually have image captions for various reasons, and the photos are just illustrative. However sometimes an image might not get a caption because it was overlooked.

As you've mentioned, picture captions are great for accessibility across the magazine and starting from next issue we're going to keep a closer eye on our image labelling with this in mind.

▲ Like this image of a Raspberry Pi 5, all images should have a caption on them

Third birthday

I saw that Raspberry Pi was celebrating its third birthday? I thought it came out in 2012?

Terry via Mastodon

Raspberry Pi was released on February 29 2012, so the joke is that it only has a true birthday on leap years – 2024 is the third leap year since it was released, hence 'third birthday'. It's not like we don't celebrate it every year though.

▲ We do not recommend serving your Raspberry Pi board in this way.

Contact us!

- ▶ Mastodon **magpi.cc/mastodon**
- ▶ Threads **@themagpimag**
- ▶ Facebook **magpi.cc/facebook**
- ▶ Email **magpi@raspberrypi.com**
- ▶ Online **forums.raspberrypi.com**

Community
Events Calendar

Find out what community-organised Raspberry Pi-themed events are happening near you...

01. CamJam's Raspberry Pi Birthday Party

📅 **Saturday 2 March**
📍 **William Gates Building, Cambridge, UK**
▶ **magpi.cc/cjrpbp**

CamJam celebrates Raspberry Pi's third (official) birthday! The first ever Raspberry Pi computer was released 12 years ago, but its birthday was February 29th! So while it's 12 years old, this is only the third time we have been able to throw it a proper bumper birthday party

02. Kanpur Raspberry Jam BIG Birthday Weekend

📅 **Sunday 3 March**
📍 **MakerSpaceKanpur, Kanpur Nagar, India**
▶ **magpi.cc/krj139**

We're celebrating Raspberry Pi's birthday at this special Jam. The topics are:
- Getting started with Raspberry Pi 5: Mr. Vivek & Himanshu
- Sensors data using Raspberry Pi: Mr. Shivam & Hitanshu
- Raspberry Pi Pico Workshop: Mr. Harsh & Abhay

There will be lots of other tips and tricks by makers. Please bring your Raspberry Pi or a charged laptop (either one is required).

03. Raspberry Pi for Science Buskers

📅 **Friday 8 March**
📍 **Usap School, Harare, Zimbabwe**
▶ **magpi.cc/rpsb139**

The Raspberry Pi for Science Buskers event provides high school students with a rich and engaging set of activities related to the use of Raspberry Pi.
The goals are:
- To encourage them to use the Raspberry Pi in science busking and projects.
- To promote a general interest in STEM among high school students.
- To inspire the development of coding clubs in Zimbabwe.

FULL CALENDAR
Get a full list of upcoming community events here:
magpi.cc/events

04. Raspberry Jam WV 2024

📅 **Saturday 16 March**
📍 **University of Charleston, Charleston, WV, USA**
▶ **magpi.cc/rjwv139**

Join us for a fun-filled day at the University of Charleston in Charleston, West Virginia. This in-person event is a must-attend for all tech enthusiasts and lovers of Raspberry Pi computers. Featuring the brand-new Raspberry Pi 5!

RASPBERRY PI EMBEDDED WORLD 2024
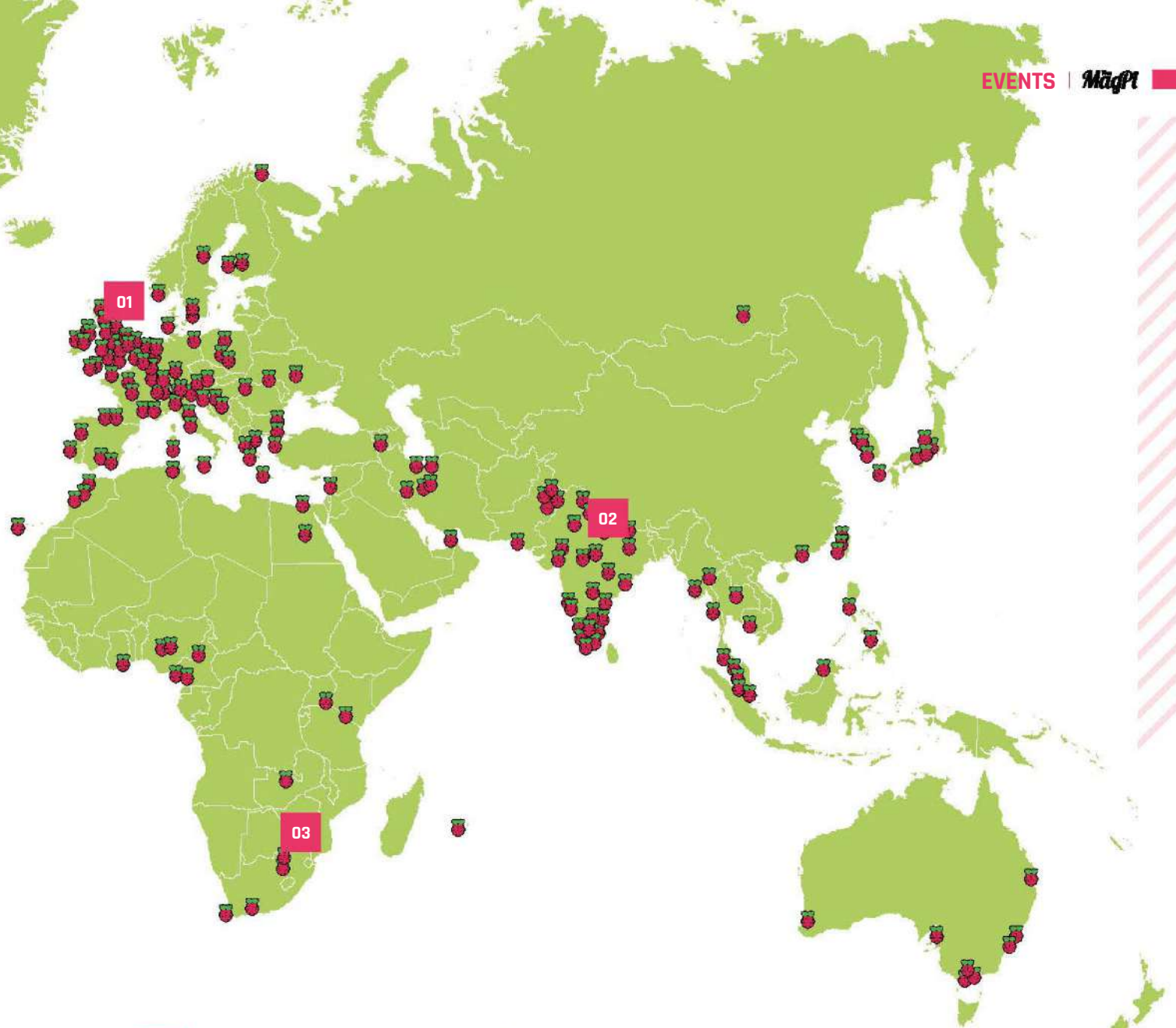
Embedded World 2024

> Where   **NuremburgMesse, Nuremburg, Germany**
> When   **Tuesday 9 April to Thursday 11 April**

"The Raspberry Pi team is looking forward to returning to Embedded World in 2024. There you'll be able to meet us and experience demos of the full spectrum of Raspberry Pi products, including Raspberry Pi Pico, RP2040-based solutions, Compute Modules, and Raspberry Pi computers, as well as the High Quality Camera and Camera Module 3."

magpi.cc/ew2024

WIN ONE OF FIVE

ARGON ONE V3 CASES!

The Argon ONE series of cases is one of our favourites – they're very sturdy, allow for excellent heat dissipation, and they look very cool too. This new version has been created for Raspberry Pi 5 and we have five to give away.

Head here to enter: magpi.cc/win | **Learn more: magpi.cc/argononev3**

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Raspberry Pi

Turn your tech dreams into reality with Raspberry Pi

The Magpi **#140**
On sale **28 March**

Plus!

Raspberry Pi 5 & Pico

Liquid cooling Raspberry Pi 5

Program a MIDI synth

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FACEBOOK	magpi.cc/facebook
EMAIL	magpi@raspberrypi.com
ONLINE	forums.raspberrypi.com

Design updates

We're now designing the magazine in house. It's
Raspberry Pi through and through! By **Rob Zwetsloot**

Did you notice a difference in
the magazine this month?
We've made a big change in
how we make *The MagPi* as of this
issue, as we had the incredibly
talented art and design team at
Raspberry Pi put together the mag.
They've been doing the cover for
us for a while now (it's a very
important and involved step in
magazine production) and I'm really
happy with how this issue is turning
out thanks to the efforts of Sara,
Nat, Jack, and Brian!

These are the folks that put
together all the packaging and
printed materials you see with
official Raspberry Pi products, which
I always think is fantastic. To have
that expertise here on the magazine
makes me think we come off as just
that little more official.

Past design

We wouldn't be where we are today
without the excellent team at Critical
Media though – Lee, Sam, Dougal and
the many people who have worked on
The MagPi in the past helped shape
the look of the magazine and we're
really proud of the top notch design
we've managed to maintain since the
relaunch in 2015.

I also appreciate them trying
to indulge me in a fun idea I had

several years ago – if you cast your
mind way back to issue 52 (**magpi.
cc/52**), there was a Christmas tree
on the cover. I had a grand plan of
showing people how to turn it into
a Christmas card. We looked into
having holes punched into the cover
at the right spots but unfortunately
we weren't able to make it happen,

so we had to recommend readers
poked their own holes in it –
something not every reader wanted
to do with their beautiful new issue.

I believe some people did try the
Christmas card tutorial in the end,
however the rest of the magazine
was a bit heavy and it didn't quite
work as I'd hoped. I'm glad we
tried though.

Creation is hard

There is a lot of work that goes into
making each issue of the magazine
from a lot of people behind the
scenes – if you look back to the
previous page we have a thing called
a 'flannel panel' which credits
everyone who works on the mag.

From our great design team, to
our wonderful freelancers, our ads
manager, and many more people
who are part of the great chain that
results in a *MagPi* in your hands
each month.

Why is it called a flannel panel?
Apparently nobody knows. I've never
washed my face with it, at least.

> **There is a lot of work that goes into
> making each issue of the magazine
> from a lot of people behind the scenes**

It's important to be there though
as while I am pretty incredible,
there is no way I can make all of the
magazine myself – Adobe InDesign
frankly scares me – and highlighting
the great people who support us
is the least we can do (aside from
paying them for their work, which
we do as well).

Anyway, I look forward to seeing
more from our new team. See you
next month!

Rob Zwetsloot

AUTHOR

Rob has been working on model kits a
lot recently. They're a bit small to fit a
Raspberry Pi Pico, but he has a bigger
kit in the pile to build…

magpi.cc